Strategic Learning and Corporate Investment[*]

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Abstract

We show that firms *anticipate* information spillover from peers' investment decisions and delay project exercise to learn from them. While this information improves project selection, the cost of waiting offsets those gains. To establish causality, we exploit local exogenous variation from the 1800s that shapes the number of peers that a firm can learn from today. The effect is most salient when the cost of waiting is low, the project has low expected profitability, and the source information is more relevant. Finally, the anticipation of peers' information spillover dampens aggregate investment, suggesting a role for this mechanism in macro-investment models.

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1 Introduction

Corporate decisions convey information. Building a plant, divesting from an industry, entering a new market, or paying dividends makes public portions of a firm's private information set. In turn, a firm's peers can learn from this revelation and adjust their behavior. This type of information spillover is well known to impact corporate innovation, financial policies, and investment decisions (e.g., Jaffe et al., 1993; Conley and Udry, 2010; Bloom et al., 2013; Leary and Roberts, 2014; Bustamante and Frésard, 2020; Décaire et al., 2020). Despite this evidence, it remains unclear whether or how pure information spillovers from peers affect firms' decisions *before* the information is revealed. Building on existing theoretical work, which formalizes this dynamic for firms' investment policies, we investigate this question empirically.[1] In particular, we examine how the quantity of information expected to be released by peers impacts the timing of large-scale corporate investments.

Two features of theory constitute the backbone of this study. First, a firm's incentive to delay its investment grows with the amount of information expected to be released by its peers. This arises from each firm's desire to take advantage of the private information revealed by the decisions of its peers and make better-informed investments. In equilibrium, a war-of-attrition regarding the timing of investment decisions among peers ensues, resulting in delays. Second, the quantity of information expected to be released increases with the number of peers' real options that a firm expects to learn from upon their exercise. Together, these results facilitate a precise mapping from existing models to our empirical specification, creating a tight link between the theory and the empirics.

Our setting exploits detailed project-level data on horizontal shale oil and gas infill wells

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[1] We structure our analysis around the contribution of Chamley and Gale (1994), who develop a clean model documenting our dynamic of interest. Although they are the first to be credited with modeling this relation in a rigorous way, other studies have provided similar insights. For example, see Mariotti (1992), Zhang (1997) and Aghamolla and Hashimoto (2020).

located in Oklahoma and Louisiana from 2005 to 2020.[2] In total, we study firms' investment behavior following 8,725 distinct real options over 537,093 option-month observations. This setting offers four significant advantages for studying strategic learning and the timing of corporate investment.

First, few empirical settings are conducive to observing precise beginning and ending (exercise) dates for real options, for either a firm or its peers. While firms actively monitor their peers' strategic capacities to assess their investment opportunities, and identify which could eventually be exercised (Porter, 2008), firms do not systematically share this information with data providers. The unique institutional features in Oklahoma and Louisiana allow us to clearly identify the exact location of a firm's and its peers' real options and to observe when each becomes available and is exercised. The richness of this environment also facilitates the investigation of various economic channels through which the strategic learning of peers affects corporate investment.

Second, obtaining measures of the relevant factors explaining the exercise of real options is rarely possible. The type of projects included in our analysis—oil and gas wells—all share a simple production technology and extract the same natural resources. Further, existing regulations make it possible to observe each project's production level, as well as project cost, cash flow, and other attributes to characterize the incentives for exercising real options (e.g., Dixit and Pindyck, 1994; Kellogg, 2014; Covert, 2015). This enables us to obtain a reasonable measure of a project's economic potential while facilitating the comparison across projects.

Third, as suggested by executives' interviews and business case studies, the incentive for firms to wait and learn from peers is likely to exist in many industries (Tran et al., 2012; Kopel and Löffler, 2008). For example, certain automakers preferred to wait and learn from the decisions of their peers to confirm how to best enter the electric car market. Executives

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[2] As described in Section 3.2, an infill well is the second well drilled on a leased section, which is a standard unit of land measurement in the American Public Land Survey System that corresponds to a one-mile by one-mile square.

at Volkswagen have hinted that the company followed this strategy, saying *“Tesla has set some important and good impulses in the industry, but Volkswagen is rather a second mover, who would rather check a couple of times more whether [those] standards are right"* (Reuters, 2017). Similarly, business case studies have documented that Apple Inc. has adopted such a strategy when introducing many of its iconic products (Boddie, 2005).

Empirically, however, it is rarely possible to distinguish between the effect of pure information spillovers and other strategic motives, such as the first-mover advantage. Our analysis focuses on infill wells, which are wells drilled after firms have acquired the mineral rights from the landowners and an initial well has been drilled. For infill projects, the drilling decisions of one firm have no material consequences on the underlying value of its surrounding peers' options, other than through the private information that is disclosed. That is, there is no common pool problem as discussed in Kellogg (2014). Further, there is little in the way of a first-mover advantage. Effectively, each firm behaves like a monopolist on its plot of land. By muting these alternative mechanisms, this setting enables us to cleanly measure the impact of pure information spillovers.

Finally, it is challenging to disentangle the effect of the number of available real options (from which a firm can learn) from the underlying asset quality. On the one hand, a large number of peers acquiring options adjacent to a firm's assets may be associated with positive expectations regarding the underlying asset potential. On the other hand, large sets of unexercised options in a project's vicinity may suggest that peers have received negative signals regarding the asset's fundamentals. Indeed, if peer firms acquire private information indicating that their project has limited potential, they may find it optimal to delay or forgo exercising the option altogether. In this sense, the absence of firm investment may convey information about the underlying asset quality (Giglio and Shue, 2014; Jin et al., 2021). Ultimately, these competing explanations are likely to confound any non-causal analysis.

To address this concern, we combine three empirical strategies to control for underlying asset quality and obtain exogenous variation in the number of peers with real options in a well's vicinity. First, in our main analyses, we include controls for the quality of the wells previously drilled by the firm and its peers in the region. Second, we control for time-invariant geographic characteristics associated with the region in which the option is located. These first two strategies are meant to capture variation in the underlying asset quality that may simultaneously impact drilling decisions and the number of peer options.

Our main result shows that an increase in the expected quantity of information to be released by peers increases firms' incentive to delay investment decisions. In particular, a one-standard-deviation increase in the number of nearby peer options reduces the likelihood of project exercise by 13 percent at any given point in time. Moreover, in the cross-section, we find that firms appear to trade off the gains from collecting additional information from peers with the associated costs of waiting for it. In particular, we show that the intensity of a firm's incentive to wait for peers' information spillover declines as firms' cost of capital increases, consistent with the argument that higher discount rates make it more costly to wait. However, we also find that firms tend to wait less on their peers when the information they have already obtained signals higher expected profitability.

Importantly, these cross-sectional results square with our findings regarding project performance. Specifically, while we show that firms select and design projects that are 8.3% more valuable as a result of waiting on peers' spillovers, our back-of-the-envelope calculation suggests that the corresponding delays cost firms 7.4% of the project's value in pure time-value-of-money terms. Although the benefits of waiting appear to offset the costs from the firm's perspective, the delays ultimately induce sluggish investment. Lastly, we show that firms are willing to wait more for sources with information content of greater relevance, such as the information revealed by (a) similar projects, and (b) skilled peers.

Our third empirical strategy introduces a novel instrumental variable that uses arbitrary variation in historical landownership fragmentation in the region surrounding a firm's option. We exploit Bureau of Land Management (BLM) data on parcels deeded to settlers by the Federal Government through multiple land grant programs enacted throughout the 1800s and early 1900s. Specifically, our instrument measures the number of *original* landowners in the region where a firm ultimately establishes a real option.[3] Smaller values of landownership fragmentation indicate that a firm can collect the drilling rights of most of its surrounding sections relatively easily, for example, by communicating and coordinating with few individual landowners today. Conversely, larger values suggest that a firm must approach numerous landowners to lease the drilling rights for an otherwise similar group of sections, significantly raising the present-day coordination costs (Leonard and Parker, 2021). Because these coordination costs affect the ability of a firm to successfully collect the drilling rights of all neighboring sections before its peers acquire any, it impacts the share of local private information held by the firm versus that held collectively by its peers.

This strategy strongly captures how firm-landowner coordination costs affect the number of available options held by any of the firm's peers in a region, as F-statistics are over the critical threshold in all specifications (Staiger and Stock, 1997; Stock and Yogo, 2005). Figure 1 displays a robust positive relation between the instrumental variable and the average number of options held by a firm's peers, measured for each region in our sample. The results from the two-stage Cox instrumental variables analysis validate the conclusion from the reduced-form models and give our findings a causal interpretation.

Finally, we document that these project-level informational externalities impact aggregate investment. Specifically, a one-standard-deviation decrease in the concentration of firms holding options at the regional level is associated with a 19% decrease in the total number of options exercised over our sample period. Ultimately, this evidence has implications for studies investigating aggregate investment behavior under uncertainty (e.g., Bachmann et al., 2013; Ilut and Schneider, 2014; Basu and Bundick, 2017; Bloom et al., 2018; Baker et al., 2020) and with peers' learning (e.g., Rob, 1991; Veldkamp, 2005; Nieuwerburgh and Veldkamp, 2006; Fajgelbaum et al., 2017). While supporting these models' key assumptions,

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[3] To validate our use of historical data, we present evidence showing that landownership fragmentation is persistent over time, as the historical measure explains 45% of the contemporaneous landownership fragmentation within a county.

our results present a novel set of micro-level evidence showing that the *anticipation* of peers' information spillover further amplifies investment delays in the aggregate. Simultaneously, our analysis identifies key characteristics that may impact the responsiveness of industry-level investment during and immediately following recessions.

We also contribute to several strands of the literature in finance and microeconomics. First, we add to an evolving understanding of how firms set investment policies within a real-options framework (Grenadier, 1996; Tufano, 1996; Grenadier, 1999, 2002; Grenadier and Wang, 2005; Novy-Marx, 2007; Grenadier and Malenko, 2011; Kellogg, 2014). Second, our paper contributes to a growing literature on peer effects, strategic interactions, and firm policies (Caplin and Leahy, 1994; Gul and Lundholm, 1995; Leary and Roberts, 2014; Foucault and Frésard, 2014; Décaire et al., 2020; Bustamante and Frésard, 2020).

Finally, our paper is closely related to Décaire et al. (2020), who document that the timing of a firm's options exercise is strongly influenced by its peers' exercise behavior, consistent with an information revelation channel (Grenadier, 1999). However, whereas Décaire et al. (2020) find that firms speed up investment after positive private information is revealed by peers' actions, we document that the anticipation of private information being released through their peers' investment decisions delays firms' corporate investment. Combined, these two results reflect Chamley and Gale' (1994) equilibrium in a complementary way: periods of sluggish investment due to strategic learning incentives among peers can be followed by intense investment cascades.

2 Model of Investment Delay and Information Spillover

Chamley and Gale (1994) model firms' investment decisions as a multiplayer game in which each firm, with some positive probability, is endowed with a profitable, yet risky investment opportunity (real option). Though the returns to exercising this option are not certain, they are positively correlated with each firm's private information. This private information becomes publicly available only when a firm makes the investment. Because the model is one of pure informational externalities, there are no other meaningful competitive forces, such as first-mover advantage. Then, in equilibrium, firms delay exercising their options as they wait to observe peers' decisions.

The authors are careful, however, to note that there are two potential (non-mutually exclusive) motives that may explain why firms delay their investment decisions. First, it is possible that firms simply expect that their investment will be unprofitable. That is, the expected value of extracting the underlying asset is below the threshold and firms delay the investment decision until they can confirm that it is profitable in expectation. Second, firms have pure learning incentives and find it valuable to wait an additional period prior to exercising. The benefit of such a delay stems from the quantity of information expected to be released in the following period. Thus, if delaying investment and learning from their peers sufficiently updates their priors compared to the current period's valuation, waiting is net present value positive. In Chamley and Gale's (1994) notation, we can express this as

$$\delta W(\xi, h) > v(h) > 0; \text{ Proposition 4.} \tag{1}$$

where δ (i.e., $0 < \delta < 1$) is the firm's discount factor, ξ is the amount of information expected to be released next period, and h is the number of peer investment decisions that have already been made. Then, $W(\xi,h)$ denotes the undiscounted investment value after waiting an additional period for a given pair (ξ,h), and *v(h)* is the expected investment profitability this period conditional upon only the exercise of h peer real options. The authors further show that the value-to-wait ($W(\xi,h)$) increases with the expected amount of information to be released next period (ξ).

In sum, Proposition 4 provides two empirical predictions. First, there exists an equilibrium in which the amount of information expected to be released next period is sufficiently high that some firms find it valuable to delay investment decisions, even when investment is already expected to be profitable in the current period. Second, the incentive to wait for peers information spillover is decreasing in the time-value-of-money.

Providing further structure for our empirical work, Chamley and Gale's (1994) Lemma 2 shows that the expected quantity of information to be released in a period (i.e., ξ) is positively related to the number of peer options. Intuitively, in our setting, the more peers' options surrounding a firm's option in a given period, the greater the number of options the firm expects to be exercised *next* period in each state of the world with respect to the underlying asset quality. Combined, these results allow us to directly map our empirical analysis into Chamley and Gale's (1994) theoretical framework.

3 Institutional Details

This section explains essential features and advantages of our institutional setting. In particular, we focus on horizontal infill oil and gas wells located in Oklahoma and Louisiana to solve two key challenges that have hindered researchers: clearly characterizing the details of investment opportunities and sharply identifying peers.

3.1 Land Use Details

Shale resources, or plays, are located in nearly thirty states across the U.S. We focus our analysis on Oklahoma and Louisiana for several reasons. Oklahoma and Louisiana are behind only Texas and Pennsylvania in annual natural gas production (Kopalek et al., 2019). Thus, these two states represent a significant portion of the country's total horizontal oil and gas wells.

More importantly, however, two institutional land features in Oklahoma and Louisiana make these states particularly suitable for our analysis. First, the land survey method used in both of these states is the rectangular survey system.[4] Figure 2 depicts the difference between the rectangular survey system used in Louisiana, and that of Texas, which was originally surveyed using the mete-and-bound method. In particular, the rectangular survey

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[4] This survey method, also called the Public Land Survey System, was created by the Land Ordinance of 1785.

method creates standardized land units called sections that each measure one mile by one mile (640 acres), as opposed to the patchwork of irregular land lots in states such as Texas. Importantly, this provides us with a well-defined unit of land on which a firm can drill its initial and infill wells.[5]

Moreover, both Oklahoma and Louisiana have simple and well-defined spacing requirements for horizontal well drilling (i.e., the minimum number of acres to be acquired by a firm to drill a well). Conveniently, oil and gas firms operating in Louisiana and Oklahoma acquire the leasing rights to an entire section to satisfy the regulatory spacing requirement for horizontal wells in these two states. In contrast, such standards are much less prevalent in other states. This lack of structure makes it difficult to cleanly associate a real option with a specific well. Combined, these institutional features make it particularly advantageous to study real option exercises in Louisiana and Oklahoma.

3.2 Horizontal Infill Wells

Aside from concentrating on specific states, we also focus on a particular type of corporate investment project—horizontal *infill* oil and gas wells—a strategy first introduced by Kellogg (2014) and Décaire et al. (2020). Infill wells in Oklahoma and Louisiana are nearly identical, as horizontal drilling proceeds similarly in both states. First, firms secure the drilling rights for a section by contracting with the local landowners. These initial drilling leases typically expire after three years if the firm has not drilled at least one well on the section. However if a well is drilled during the contract term, the section becomes "held-by-production." This grants the firm with an option to further develop the section with additional "infill" wells, so long as the first well remains in production. Figure 3 provides a graphical example of a township that includes a section with no wells, a section that is held-by-production, as well as a section with a drilled infill well (a section in which the option has been exercised). Such

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[5] In practice, it is possible for firms to drill longer wells spanning multiple sections. This is the case for 9% of the options in our sample. To confirm that these non-standard infill wells are not driving our results, Table 8 Panel D presents results using a subsample of shorter wells drilled on one section.

a strategy of focusing on infill wells offers several benefits in the context of studying real options exercise and pure information spillovers.

First, because of the nature of infill wells, along with the specific features of the states we analyze, we are able to circumvent the most challenging data limitation in studying real options—simply observing when a firm holds a real option. In particular, we are able to measure exactly when the real option becomes available to the firm as it corresponds to the date a section's initial well is drilled. Likewise, we can observe the precise date each option is exercised (the date the first infill well is drilled), or if the option goes unexercised over the course of our sample. Moreover, due to the rectangular survey method and minimum spacing requirements, there is no confusion about whether a newly drilled well is an infill well. That is, we are able to precisely define newly drilled wells as either the start of a new option, or the exercise of an existing option, simply by observing the section in which it is drilled.

Second, pure learning incentives are generally difficult to disentangle from other competitive strategic actions, such as the first-mover advantage. However, in the context of our analysis, firms have monopoly power over their section, meaning that no other firm can attempt to drill on the section before they do. At the same time, because shale resources are trapped between tightly packed sheets of rock, the extraction zone of horizontal wells is highly localized. Combined with spacing regulations (i.e., a set of rules preventing firms from drilling too close to each other) horizontal wells are unlikely to face a common pool problem generally leading to a tragedy of the commons. These features allow us to rule out other confounding explanations (first-mover advantage) and cleanly identify the impact of pure information spillover.

Third, the unique institutional features of our setup allow us to clearly map Chamley and Gale's (1994) model into our empirical analysis, while directly characterizing the majority of the information that firms obtain once their peers exercise an option. Precisely, the information released by an exercised option can be broken down into three categories: (1)

peers' beliefs regarding well profitability (i.e., partially revealing private information), (2) information regarding the wells' realized outcomes, and (3) engineering techniques used to extract the oil and gas. Our main variable of interest, *Unexercised Investment Opportunities (Peers)*, captures the potential release of all three sources of information. Further, given the nature of our empirical setting, we have the ability to control for the first and second source of information in our regression design.[6] Finally, data on the engineering techniques used by a firm's peers is not widely available; however, this omitted variable is unlikely to be correlated with our instrumental variable.

Finally, infill wells tend to be long-maturity options. Short-dated options, such as initial drilling decisions to hold by production, make it difficult to disentangle the different factors that predict exercise, as firms tend to systematically trigger these options quickly before they expire (Herrnstadt et al., 2020).[7] Because lease contracts stipulate that firms can drill infill wells so long as the initial well is producing, the expected maturity of each real option in our setting corresponds to the expected productive life of a horizontal well, which ranges between 20 to 40 years (see, e.g., Blum, 2019).[8]

3.3 Identifying Peer Firms

Beyond the difficulties associated with observing real options, studying strategic interactions and learning incentives presents a second challenge. That is, precisely identifying peers in a corporate setting is empirically difficult. Prior literature has proposed methods based on industry (e.g., Leary and Roberts, 2014, Grennan, 2019) and product similarity (Foucault and Frésard, 2014; Hoberg and Phillips, 2016). Each of these measures of peer influence has

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[6] We confirm that positive measures of these two sources of information are associated with a greater likelihood of option exercise. That is, in Table 2, the positive coefficient associated with the variables *Cumulative Number of Wells Drilled* and *Peers' Wells' Mkt. Value* yield support for this claim.

[7] Though firms may also learn from the timing and drilling outcomes of their peers' initial wells, the fact that they are typically drilled at the very moment leases are set to expire dampens the information contained in such decisions. This further motivates our use of infill wells as the set of real options firms can learn from.

[8] 70% of wells drilled in the first year of the sample were still active in 2020, with an average age of 13 years. For a more complete picture of the wells' life expectancy per vintages, see Internet Appendix Figure IA.1.

strengths and weaknesses. For example, identifying peers based on industry classifications such as NAICS or SIC codes is simple, yet crude. Such broad strokes cannot separate between competitors or firms within the same supply chain.

Again, the organic features of our setting provide two significant advantages. First, all of the firms in our sample are active in the same industry: oil and gas exploration and production. Second, the projects we analyze are homogeneous in their characteristics; they share the same horizontal drilling technology and produce the same resources, oil and gas. This allows us to more cleanly identify comparable projects held by a firm's peers without the need to rely on noisy proxies usually employed in the literature.

Ultimately, our strategy exploits the relative homogeneity amongst the projects and firms in our sample, along with the benefits of land policy and infill wells in Oklahoma and Louisiana to define our main variable of interest: the number of real options held by a firm's peers. In spirit, our strategy to identify peers is similar to that of Conley and Udry (2010). Specifically, *Unexercised Investment Opportunities (Peers)* equals the number of "held-by-production" sections owned by different operators located within 3 miles of a firm's own option.[9] That is, we concentrate on sections owned by peers with an initial drilled well, but no drilled infill wells. Figure 3 provides a visual of this construction for the real option highlighted in the red square.

4 Data and Methodology

Our main dataset, which was provided by DrillingInfo, covers all horizontal wells drilled in both Oklahoma and Louisiana between 2005 and 2020 (see Figure 5 Panel A).[10] This dataset includes each well's drilling start date, along with a set of project characteristics such as the

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[9] This distance, when branching in all directions, mimics the size of a township; however, as we show in Internet Appendix Table IA.1, our results are not sensitive to this particular choice. In addition, peer options located in the close vicinity of a firm's option are likely to convey more precise informative about the underlying asset quality, as the correlation between the production of wells declines quickly as the distance between wells increases (see Figure 4.)

[10] For a full discussion of the DrillingInfo dataset, see Décaire (2021) and Décaire and Sosyura (2021).

well's GPS location, and lateral length. Our final data panel consists of section-month observations, where a section enters the sample when the option to infill a well becomes available and remains in the sample until an infill well is drilled, or our sample ends. In total, we analyze 537,093 section-month observations covering a total of 8,725 unique options and 442 distinct firms. Overall, 39.7 percent of the options are exercised during the sample period.

We augment these data points with five additional data sources. First, we use hand-collected measures of per-project capital expenditures (which includes per-horizontal-foot drilling costs) and estimated operational costs obtained from public filings and regulatory documents, as in Décaire et al. (2020). We use this data to obtain time-varying estimates of the cost to drill an infill well in each month, based on the horizontal length and per-foot drilling cost of the first well drilled on that section. Second, we add monthly financial market data, such as the eighteen-month crude oil futures prices and implied volatility from Bloomberg, and the ten-year risk-free rate obtained from the Federal Reserve Bank of Saint Louis. The eighteen-month futures contract is well-suited for our analysis because a horizontal well's half-life (the amount of time it takes to receive half of the well's production) is equivalent to that horizon. Moreover, Kellogg (2014) shows that implied volatility best captures forward-looking uncertainty.

The next two sources consist of data on landownership. The first is from the Bureau of Land Management and contains information on original property rights allocated to settlers via federal programs in the 1800s and 1900s.[11] We use this data to construct our instrumental variable. The second source contains oil and gas lease data, provided by DrillingInfo, which contains information on contemporaneous landownership. The DrillingInfo lease data have issues that limit their use in our empirical strategies. In particular, we only observe landownership fragmentation for sections that are ultimately leased by oil and gas firms. However, it does facilitate a reasonable test to explore whether historical landownership

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[11] It is possible to access the BLM data using this link `https://glorecords.blm.gov/BulkData/`.

fragmentation patterns have explanatory power over contemporaneous landownership fragmentation. Ultimately, it allows us to confirm existing empirical studies that document such patterns in different environments (e.g., Curry-Roper (1987)).

Finally, we collect the announcements of strategic alliances and joint ventures from Thomson Reuters SDC Platinum. These data allow us to roughly observe firms that utilize such partnerships over the course of our sample period. All the variables constructed from these data sources are defined in Internet Appendix Table IA.2.

Table 1 presents summary statistics for the data used in our main regressions. In particular, Table 1 suggests that for each of the options a firm owns, there are, on average, four of its peers' unexercised options, and five of its own unexercised options, located in the surrounding region. Moreover, the average firm in our sample owns 19 options. Additionally, Table 1 displays the summary statistics for both firm- and well-level covariates, as well as financial market variables for the oil and gas industry.

Similar to studies such as Leary and Roberts (2005), Whited (2006), and Wittry (2021), we employ a Cox proportional-hazards rate model to capture our dynamic of interest. This type of model provides a natural way to explore how strategic learning incentives among peers affect the timing of exercising real options. Specifically, for a random duration of time T, we can cast the hazard function of our problem such that

$$h(t) = \lim_{m \to 0} \frac{\Pr(t \leq T < t + m | T \geq t)}{m} \tag{2}$$

In this equation, $h(t)$ denotes the instantaneous rate at which a firm is likely to exercise its real option conditional on not having exercised it at time t. Put differently, we can interpret $h(t)$ as the probability that a firm will exercise its real option during the next period m, conditional on not having exercised it up to time t. In the context of our analysis, this duration model allows us to measure the effect of strategic learning incentives among peers between the time a real option becomes available and the time it is exercised.

5 Main Results

We start our analysis by considering the impact of peer options on the timing of investment decisions in a generalized way. We separate firms' investment opportunities in two subsamples: those for which there are no peer options in its vicinity for the entire life of the option, and those for which there is at least one nearby peer real option at any point in the option's life. Figure 6 plots the Kaplan-Meier survival function for each of these groups of projects. This empirical specification offers a number of advantages. First, the survival functions represent an intuitive visual of exercise likelihood over time. Second, the comparison of survival probabilities provides an initial nonparametric estimate of firms' incentive to wait when they have the potential to learn from their peers.

Consistent with theory (e.g., Chamley and Gale, 1994), Figure 6 displays a stark difference in survival probability between the two subsamples. Further, the 95% confidence intervals do not overlap, indicating that at all points in event time, the probability of exercise for projects in an environment with peer real options is statistically different than for projects with no peers. This suggests that the anticipation of private information release through peers' option exercise significantly impacts the timing of firms' investment decisions.

Moreover, the delay induced by potential information spillover can be quite large. For example, the difference in the average time to exercise projects in each respective group is 9.5 months. From a pure time-value-of-money perspective, waiting an additional 9.5 months before drilling costs the firm 7.4% of the project's net present value.[12] However, in our sample, these costs appear to be offset by the observed benefits associated with the information collection. In particular, Internet Appendix Table IA.3 presents models that highlight the gains associated with peers' information spillovers, which translate into superior project selection. Precisely, projects with the possibility of peers' information spillovers are associated with an economic value that is 8.3% higher than the corresponding project

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[12] The value reduction is equal to $\left[1-\left(\frac{1}{1+R_{CAPM}}\right)^{\frac{9.5}{12}}\right] \times NPV = (1-7.4\%)\times$ NPV.

with no nearby peer options.[13] Thus, firms appear to jointly consider the costs of waiting for additional information and the benefits that result from obtaining such information. However, the overall learning dynamic still works to delay firms' exercise decisions, which results in sluggish investment responses.

5.1 Baseline Multivariate Hazard Model Results

To refine and deepen our analysis, the remainder of the paper focuses on multivariate Cox hazard regression models with a continuous measure of the potential available information spillover.[14] The Cox model is flexible enough to include a host of time-varying control variables that are likely to impact project exercise. Further, we use stratification at the county level to account for geographic time-invariant unobservable heterogeneity. For example, the quality of the underlying assets in a specific geographic region is likely to be highly correlated (e.g., see Figure 4). Like fixed effects, the county strata remove the portion of an exercise decision that is attributable only to geographic location; however, in a repeated-events (multiple options exercised per strata) setting such as ours, they do so in the Cox setting without inducing incidental parameter bias (Allison, 2002). Finally, because our treatment is geographically based, we cluster our standard errors at the county level (Petersen, 2009; Abadie et al., 2017).[15]

Table 2 reports the results of our baseline Cox hazard models. Our main independent variable of interest is *Unexercised Investment Opportunities (Peers)*, which measures the number of real options held by a firm's geographic peers. To facilitate the interpretation of the regression coefficients, we also report the hazard impact percentage, which equals

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[13] Gains for the average project that has surrounding peers = 0.068*1.22.

[14] The continuous measure of available information spillover most closely matches the model in Chamley and Gale (1994). However, our results are not sensitive to this modeling decision. Internet Appendix Table IA.4 reports specifications that use an indicator variable equal to 1 for projects with any positive number of peer options. The results in these tests are quantitatively and qualitatively similar to our main results below. Further, Table IA.5 shows that our main results are robust to alternative econometric specifications such as an OLS or Probit model.

[15] Wells in the same county are likely to share similar characteristics and thus, face a similar probability of being exercised. Internet Appendix Table IA.6 shows that our inferences are not sensitive to this particular choice of cluster level.

$100 \times (Hazard\ Ratio - 1)$. This corresponds to the percentage change in exercise likelihood given a one-unit change in the variable of interest. The coefficient on *Unexercised Investment Opportunities (Peers)* in Model (1) is -0.030 and is statistically significant at the 1% level. The hazard impact percentage for this coefficient is -2.93%, which suggests that a one-standard-deviation increase in the number of real options held by peers reduces project exercise likelihood by 10.7%.

Model (1) also includes multiple control variables. We start by including firm- and region-level covariates that are likely to impact project exercise. For example, we include the total number of wells drilled in the vicinity. This proxies for the time-varying drilling potential of the region, as Décaire et al. (2020) show that peers' decisions to drill induce firms to positively update their beliefs about the underlying asset quality and speed up their investment decisions. Further, we control for the additional investment opportunities the firm has in the same region, the firm's geographic dispersion as measured by the mean distance between its options, and finally, measures of the firm's skill and its portfolio concentration.

Models (2) and (3) add additional covariates at the project- and market-level, respectively. In particular, in Model (2), we add standard inputs in real options models (Dixit and Pindyck, 1994), such as a proxy for the option's underlying asset quality (i.e., the market value of the first well dug in the section), the estimated cost of drilling the well, and the first well's lateral length.[16] Moreover, Model (2) includes the market value of a firm's peers' average wells to proxy for the signal of quality the firm receives, the first well's oil-to-gas ratio, and finally, a measure of the average royalty rate for the township in which the option is located. The royalty rate represents the fraction of the well's cash flows that must be paid to the landowners. A higher royalty rate may be associated with higher quality underlying assets, but it could also capture the overall bargaining power between landowners and oil

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[16] Though the outcome of a section's first well does impact the timing of the infill well (its coefficients in Models (2) and (3) are positive and significant), it rarely supplies a firm with all the information it needs to know if an infill well will be economically viable. For example, Figure 7 displays an excerpt from an "Increased Density" request made by Camino Natural Resources, which highlights that new information, incremental to that gathered during the drilling of the first well, justifies the need to drill an infill well.

and gas firms.

Model (3) adds the eighteen-month futures price, implied volatility of the underlying asset, and the 10-year risk-free rate. Futures price and volatility of the underlying asset have often been used as proxies for the expected cash flow and cash flow risk of the project itself (Kellogg, 2014). The addition of these control variables significantly raises the bar for alternative mechanisms to be driving our main results. Each of these controls exhibit the expected sign, and with a few exceptions, are statistically significant at least at the 5% level.

The coefficients on *Unexercised Investment Opportunities (Peers)* are larger in magnitude in Models (2) and (3). For example, in Model (3), the coefficient remains significant at the 1% level, but increases to -0.037. Given the hazard impact percentage of -3.62%, the economic magnitude is also significant. In particular, a one-standard-deviation increase in real options held by a firm's peers reduces exercise likelihood by 13.2%. This indicates the anticipation of information spillover is on the same order of magnitude in terms of importance as other drivers of real option exercise (see, e.g., Dixit and Pindyck, 1994; Kellogg, 2014). For example, a one-standard-deviation increase in futures price is associated with a 17.1% increase in exercise likelihood, while a one-standard-deviation increase in implied volatility is associated with a 11.5% reduction in exercise likelihood.

Overall, the results in Table 2 are supportive of Chamley and Gale (1994). A potential implication of the evidence presented in this section is that firms produce private information in a non-cooperative fashion even when they face little to no direct competition from their peers. Alternatively, peers may not perceive shared information as reliable, while the decision to conduct a project might credibly signal a firm's beliefs about the underlying asset potential. The remainder of this section considers several extensions to the baseline models, including a test of a supplementary prediction in Chamley and Gale (1994). Further, we explore several additional economic mechanisms that relate to our main results.

5.2 The Dynamics of the Costs vs. Benefits Tradeoff

Delayed investment in the presence of peers, on its own, does not suggest either the destruction or creation of value. Rather, such a delay likely reflects both costs and benefits to the waiting firms, as we discussed in Section 5. To better understand how firms optimize between the benefits of waiting for additional information revealed by peers, and the costs of the associated delay, we introduce two empirical exercises.

First, Chamley and Gale (1994) make the additional prediction that firms' incentive to wait for peers information spillover decreases when the time-value-of-money increases. Intuitively, higher discount rates erode a greater share of the potential gains associated with obtaining peers' information in the future. To test this prediction, we use the interaction between number of peer options and a measure of the cost of equity for the public firms included in our sample. Even with this restriction, we retain nearly 5,000 distinct real options, and ultimately, are left with a sample of 273,427 option-month observations. Then, for each firm-month in this subsample, we define the cost of equity as

$$R_{i,t}^{CAPM} = rf_t + \beta_{i,t} \times 4.32\% \tag{3}$$

Where rf_t is the risk-free rate, 4.32% corresponds to the Fama and French (2002) estimate of the market equity premium, and $\beta_{i,t}$ denotes the 60-month rolling CAPM market beta for firm i at time t.[17]

Panel A in Table 3 reports the results of the cost of equity interaction tests. The findings suggest that, across all models, firms' incentive to wait for additional information from peers' spillovers decreases as the financial cost of waiting goes up. It should be noted, however, that interpreting interaction coefficients in non-linear models is challenging, as the marginal effect is unlikely to be constant over the full support of the variable of interest

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[17] We choose a 60-month window to follow the existing literature (e.g., Kruger et al., 2015). However, Internet Appendix Table IA.7 confirms that our results are robust to alternative estimation windows, such as 48- and 72-month horizons.

(i.e., *Unexercised Investment Opportunities (Peers)*). For this reason, we apply the same strategy as recent empirical studies (e.g., Alesina and Fuchs-Schündeln, 2007) to establish a meaningful interpretation of the interaction term.[18]

Specifically, for Model (3), the cross-partial derivative coefficient for the interaction term when evaluated at the mean of *Unexercised Investment Opportunities (Peers)* (3.95) is equal to 0.003, which confirms the interpretation of the total coefficient when taken directly from the regression. We further validate this result in two ways. First, in unreported estimations, we confirm that the signs of the cross-partial derivative coefficients are positive over the full support of *Unexercised Investment Opportunities (Peers)*. Second, we re-estimate the results using a linear regression model, as the interpretation of interaction terms is more direct in that context. Panel A of Table IA.8 reports the associated OLS models. Across all specifications, the interaction coefficients are statistically significant and positive, which support the results presented in Table 3 Panel A.

As one final point regarding discount rates, we note that the real option literature provides an ambiguous prediction for the direct effect of firms' cost of capital on option exercise (Dixit and Pindyck, 1994). This arises because an increase in the cost of capital both reduces the asset's net present value and the option optimal exercise threshold, making the ultimate effect dependent on their relative declines. In the context of our analysis, we find a negative overall effect.

The second dimension on which firms are likely to trade off costs and benefits of waiting is the set of signals they have already received. In particular, when firms observe signals suggesting high underlying asset quality, their incentive to wait in anticipation of additional information weakens (Acemoglu et al., 2011). In our setting, this is equivalent to firms internalizing both how many peers exercise their options, as well as the production value of their associated drilled wells. To empirically investigate this hypothesis, we measure the

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[18] The coefficients reported in the tables are the total coefficients. However, when interpreting coefficients of interaction variables in the text, we report the corresponding cross partial derivatives evaluated at the mean (Ai and Norton, 2003).

signal of quality using the market value of the mean well drilled by a firm's peers. A high mean well value suggests that the underlying asset quality for the firm's wells is also likely to be high, and thus the incentives to wait and learn more are muted.

Panel B in Table 3 presents the results of interacting *Unexercised Investment Opportunities (Peers)* with *Peers' Wells' Mkt. Value*, which is equal to the natural log of the mean well value amongst a firm's peers. The coefficient on this interaction term is positive and significant at the 1% level in all three models. Moreover, the cross-partial derivative coefficient is 0.076 in Model (3), suggesting that the nature of the information firms receive from their peers plays an important role in determining when they have collected sufficient data on exercise value. Consistent with Acemoglu et al. (2011), this result indicates that firms' incentive to delay investment to learn from their peers is most salient when there is more uncertainty regarding the profitability of the potential investment. As with the cost of equity interactions, we find that the cross-partial derivative coefficients from Panel B are positive over the full support of *Unexercised Investment Opportunities (Peers)*. Finally, Panel B of Table IA.8 shows that the results presented in Panel B of Table 3 are robust when estimating the interaction relation with a linear model.

Together, the results in this section suggest that a firm's incentive to wait for its peers' information is traded against the cost of waiting to collect this additional information, and that it is mediated by the signals the firm has already collected from its peers.

5.3 The Relevance of Information Sources

In the underlying theory, such as Chamley and Gale (1994), firms indiscriminately value (wait for) peers and peer projects, regardless of their characteristics. Although such a model yields precise predictions, it presents a stylized view of reality, as often sources with specific characteristics may provide more relevant information. To deepen our analysis and better capture strategic learning dynamics, we borrow from existing empirical insights and extend our results in two ways.

First, we assess the role of project similarity. Peer projects with a higher degree of similarity likely contain more relevant information to the firm when exercised and should increase firms' incentives to wait for such projects. This hypothesis is consistent with Cho and Muslu (2021), who show that the content of peer MD&A reports influences firm investment, but only among peers with a high degree of product similarity (Hoberg and Phillips, 2016). Put differently, this extension is akin to measuring the quality of information content firms anticipate receiving, rather than the quality of the peers' underlying asset itself.

To perform this test, we measure similarity through the precise resource mix (oil vs. gas) of peer firm's initial wells. In our sample, the resource mix across wells is highly variable (the standard deviation of the oil-to-gas ratio is 34%). This variation suggests a degree of project heterogeneity, which can obviously impact how firms allocate their attention. Practically, we start by creating indicator variables for projects that are majority oil (e.g., oil $>$ 50% of the total resource quantity) and those that are majority gas (gas $>$ 50% of the total resource quantity). We then count separately the number of initial wells in a firm's vicinity that are the same majority resource and those that are different, and we scale each variable by its own standard deviation. Scaling the variables by their standard deviation allows us to readily compare the economic magnitude between the two estimated coefficients.

The results appear in Panel A of Table 4. Peer options from both same-resource projects and different-resource projects negatively impact exercise decisions; however, the effect is only significant for same-resource options. For example, in Model (3), the coefficient on *Unexercised Investment Opportunities (Same Resource)* is -0.138 and is significant at the 1% level, while that of *Unexercised Investment Opportunities (Different Resource)* is -0.036 and is insignificant at conventional levels. Furthermore, the coefficients are significantly different from each other (Chi^2 statistic = 15.90).

Second, we explore how the quality or skill of peers interacts with a firm's incentives to delay investment. Firms may find the information produced by the actions of their peers with a successful track record more valuable, increasing their incentive to wait for such peer decisions. Consistent with this idea, Conley and Udry (2010) and Décaire et al. (2020) present empirical evidence that firms' decisions tend to be mainly influenced by their successful peers' actions.

To assess this prediction, we compare the influence of high-skill and low-skill peers. We measure a firm's skill through the quantity of oil or gas its average well produces. That is, we define a firm to be high-skill if its mean well produces more oil or gas than the median well in our sample, and low-skill otherwise. Next, to obtain the two skill-based measures of peer options, we proceed in a similar fashion as for project similarity. In particular, we count the number of wells in a firm's vicinity that are held by high-skill peers and low-skill peers separately and we scale each by its own standard deviation.

Table 4 Panel B displays the results. In all models, the coefficients on unexercised investment opportunities held by a firm's high-skill peers are large, negative, and significant at the 1% level. Standing in stark contrast, those on low-skill peers' options are small and indistinguishable from zero. Further, in testing for significant differences between the two sets of coefficients, we find the Chi^2 test statistics are between 11.40 and 12.54, each significant at 1%. Finally, the economic magnitude of the hazard impact percentage in Model (3) indicates that a one-standard-deviation change in high-skilled peers' unexercised investment opportunities reduces exercise likelihood by nearly 14%.

The results in Table 4 suggest that the majority of the main effect in Model (3) of Table 2 (HI% × SD = -13.2%) can be attributed to firms' waiting for projects with a high degree of similarity, and for their highly skilled counterparts. Taken together, these findings indicate that firms do not indiscriminately wait on peer exercise. Rather they focus on sources that are more likely to provide them with relevant information content.

6 Omitted Variable and Instrumented Results

A potential concern with our analysis in Section 5 is that the number of options owned by peers in a region is not likely to be random. The most salient endogeneity issue is that the number of peers' real options may be correlated with the unobservable underlying asset value, that is, the quantity of the oil or gas in the ground. In this sense, our analysis is likely to suffer from an omitted variables bias (OVB).

To mitigate this concern, we introduce a novel instrumental variable based on historical landownership rights allocated to U.S. citizens through federal programs that followed the inclusion of the Oklahoma and Louisiana territories as states in the union. Specifically, our instrument—*Historical Landownership Fragmentation*—uses Bureau of Land Management data to measure the number of original landowners in the late 1800s and early 1900s that are located within three miles of where the options in our sample are ultimately established.[19]

Prior empirical work has shown that historical landownership patterns strongly explain contemporaneous patterns (Curry-Roper, 1987). That is, within a given region, a higher number of historical landowners implies a higher degree of fragmentation today, all else equal. We also verify this relationship in our data using the number of individual landowners that a firm contracts with during mineral rights lease negotiations. Figure 8, Panel A presents the visual depiction of the relationship, while Internet Appendix Table IA.10 reports regressions that suggest the number of historical landowners explains as much as 45% of the variation in contemporaneous landowners within a county.

Under the idea that fragmentation is persistent through time, Figure 8, Panels B and C present the intuition behind the use of the historical fragmentation as our instrumental variable. The panels depict landownership in two distinct townships in Woodward County, Oklahoma, as of 1910. Smaller values of historical landowners (depicted by Figure 8 Panel B) indicate that a firm is likely to be able to collect the drilling rights to multiple contiguous sections by approaching fewer individual landowners today. However, the more fragmented landownership was in the early 1900s (depicted by Figure 8 Panel C), the higher the coordination costs are likely to be today, making it harder for a single firm to acquire all the

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[19] This data covers nearly 80% of our main sample. To ensure consistency, Internet Appendix Table IA.9 shows that the results from reduced-form Cox models on the reduced IV sample are quantitatively and qualitatively similar.

sections' leases before its competitors secure the rights to some.[20] Thus, higher values of the instrumental variable suggest a greater share of the surrounding options will be held by its peers.

Panel A of Table 5 presents the first stage of our instrumental variables regression and confirms this intuition. That is, when regressing *Unexercised Investment Opportunities (Peers)* on *Historical Landownership Fragmentation*, we find a statistically significant and positive coefficient. In particular, a one-standard-deviation increase in the number historical landowners is associated with a 12% increase in the number of peer options, relative to the sample mean. Further, in each model specification, the F-statistics are above the critical threshold for weak instruments (Staiger and Stock, 1997; Stock and Yogo, 2005). This positive relation indicates that, after controlling for the number of options the firm itself owns, regions with more fragmented historical landownership are associated with a greater proportion of the total available options held by the firm's peers. Importantly, our instrument induces a wide range of exogenous variation over our variable of interest, which helps generalize the magnitude of our instrumented results. In particular, over the full support of historical landowners (1^{st} percentile through 99^{th} percentile), we obtain exogenous variation in the number of peer options that is equivalent to 93% (56%) of its endogenous standard deviation.[21]

The main identifying assumption in this strategy is that historical landownership fragmentation is uncorrelated with the option's underlying asset quality. Two arguments yield support in favor of this assumption. First and foremost, the majority of original landownership rights were allocated through federal allotments. Further, nearly 90% of the land grants were assigned to settlers before 1910, and started as early as 1821. This period not only

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[20] Investment delay is not a factor at the lease acquisition stage because the lease contracts generate negligible costs for the firm if the wells do not produce. For example, the typical lease contract stipulates an 18.75% of cash-flow royalty payment to the landowner but only an immediate "signing bonus" payment of a few hundred dollars. Thus, firms have strong incentives to acquire the rights to as many sections as possible as fast as possible in hopes of some fraction of them ultimately producing.

[21] The full range of the instrumental variable is between 1 and 310 landowners (the 1^{st} through 99^{th} is between 1 and 187 landowners). Thus, $0.93 = \frac{(\overline{IV} - \underline{IV}) * \beta_{IV}}{\sigma_{\#\ unexercised\ peers\ option}} = (310 - 1) * 0.011/3.66$. In Internet Appendix Table IA.11, we verify that our instrumented results are robust to excluding the extreme value of the historical land ownership data.

significantly precedes the fracking revolution that occurred in the 2000s, but it also took place before the first oil and gas revolution started in the early part of the 20^{th} century for the two states included in our study (see Figure 5; Blum, 2019).[22]

Four federal programs accounted for the majority of the grants: (a) the Homestead Act (42%) allocated land to American citizens willing to settle and populate the land, (b) the Dawes Act (11%) parceled out reservation land across its members, (c) the Script Warrant Acts (4%) rewarded soldiers for their efforts, and (d) cash-entry programs (39%) simply sold land titles to prospective settlers willing to farm the region.[23] This suggests that the main motive driving this initial allocation of subsurface rights to settlers was not driven by the oil and gas potential of the land, but rather it was guided by the political will to populate the American Western Territories.

Still, Allen and Leonard (2021) show that land parcels allocated under the various grant programs display considerably different commercial, industrial, residential and urban development patterns relative to parcels distributed under cash-entry programs, even centuries later. To ensure that the distribution of grant types does not complicate our instrumental variable analysis, Table 6 Panel A presents reassuring evidence indicating that the nature of the programs appears to be unrelated to the quality of the wells drilled in our setting, as measured by the market value of a section's first drilled well. In particular, the magnitude of the effect of grant type is close to zero, as a one-standard-deviation increase in a township's proportion of land parcels allocated under cash-entry programs is associated with a negligible 0.05% increase in a well's production value. Further, the p-value for the coefficient of interest in Model (1) is 0.879.

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[22] Existing empirical evidence suggests that economic activities and natural resources potential can shape the allocation of landownership (e.g., Demsetz, 1967; Besley, 1995; Galiani and Schargrodsky, 2010; Libecap and Lueck, 2011). In this sense, the predetermined nature of historical landownership rights is key to satisfying the exclusion restriction, as contemporaneous measures of landownership fragmentation are likely to be correlated with the oil and gas potential of the shale rock formations.

[23] None of the land grant programs in the BLM sample include the *Stock-Raising Homestead Act*. This distinction is key, as that particular program did not grant settlers with both the land and mineral rights, leading to a *split-estate* situation. In contrast, the four programs discussed above transferred all of the ownership rights to settlers.

Second, to further alleviate any remaining concerns regarding a link between our instrumental variable and the options' underlying asset potential, we empirically test whether historical landownership fragmentation itself is correlated with the market value of a section's first drilled well. Panel B of Table 6 reports these results. Consistent with the above assumption, we find no statistically significant effect. For example, the p-value in Model (2) equals 0.81. Further, the size of coefficient of interest is trivial in magnitude ($\beta = 0.0003$). Although no empirical evidence can unequivocally satisfy the exclusion restriction, these results are reassuring.

Tchetgen Tchetgen et al. (2015) show that two-stage least square estimation procedures yield unbiased coefficients in a non-linear second stage (e.g., Cox regressions). However, no statistical software readily includes such an approach. Thus, because the instrumented variable is a generated regressor, we must perform an adjustment to provide the proper statistical inference based on the second stage standard errors. To do so, we employ a bootstrap-based inference strategy with 500 iterations.

Panel B of Table 5 reports the second-stage Cox regression results.[24] In each model, the coefficients on *Instrumented Unexercised Investment Opportunities (Peers)* are economically meaningful and statistically significant at the 5% level. For example, the coefficient in Model (3) is -0.249, which corresponds to a hazard impact percentage of -22.02%, and is significant at the 5% level. Finally, the Kleibergen-Paap first-stage F-statistics in Model (3) is 12.1, which mitigates a weak instrument concern. In all, our instrument variables analysis suggests that the impact of information anticipation on investment timing decisions is likely to be causal.

It is worth noting that the dominant OVB problem in our setting is likely to be positive—a case of affirmative endogeneity (Jiang, 2017). In other words, the coefficients in the second-stage regressions being more negative than those in the reduced-form regressions is in line with our instrumented estimates moving toward the true value rather than away from it. To

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[24] Internet Appendix Table IA.5 shows that our results are qualitatively robust to alternative specifications, such OLS and Probit, in the second-stage.

formalize this intuition, one can decompose the OLS beta into two parts, (a) the true beta, and (b) the omitted variable bias. Specifically, this is

$$\beta_{OLS} = \beta_{True} + \underbrace{\beta_{\text{Asset Quality}} \times cov(\text{Peer Options, Asset Quality})}_{\text{Omitted Variable Bias}} \tag{4}$$

Then, it is clear that the sign of the omitted variable bias depends on two parameters: $\beta_{\text{Asset Quality}}$ and $cov(\text{Peer Options, Asset Quality})$. It is reasonably safe to conclude that more valuable projects are more likely to be exercised (i.e., $\beta_{\text{Asset Quality}} > 0$). Conversely, it is not immediately obvious whether the covariance between the number of peer options and the value of the underlying asset is negative or positive. On one hand, larger numbers of peer options clustered around a firm's assets may be positively associated with the underlying asset quality. On the other hand, large groups of idle unexercised options located in close proximity to a project might be negatively correlated with the expected value of the project.

Empirically, we observe a positive relation, which is consistent with the underlying assumption in Chamley and Gale (1994) that the expected return of the project is increasing in the number of options. In particular, Panel C of Table 6 reports linear regression models that analyze the relationship between the number of peer real options in a project's vicinity and the market value of a section's first drilled well. In both models, the coefficient on *Unexercised Investment Opportunities (Peers)* is positive and significant at least at the the 10% level. Thus, overall, it is likely that the combined OVB term has a positive sign, suggesting that our reduced form coefficients underestimate the true magnitude.[25]

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[25] The ratio between the instrumented coefficient in Model (3) of Table 5 and the reduced form Cox regression coefficients in Model (3) of Table 2 is 6.7 This magnitude is below the range reported in Jiang (2017) for affirmative endogeneity instruments.

7 Options Ownership Concentration and Aggregate Investment

The results in Sections 5 and 6 show that the anticipation of information release creates incentives for firms to wait for peers' investment decisions. Our findings indicate that firms weigh the financial costs of delaying their investment decision with the expected gain from obtaining future information from their peers' decisions. However, the strategic learning dynamic still works to make investment less responsive to economic conditions. The next step of our analysis investigates if these strategic decisions depress investment in the aggregate.

We explore this question in the context of total investment at the regional level. That is, we conduct a pure cross-sectional analysis to study the total number of options exercised over the entire sample period of 2005 through 2020. To address the fact that some regions developed earlier than others, which could impact both the expected amount of information from peers, as well as the total investment made, we include a region cohort-year fixed effect (i.e., the year the first option became available in that region). This allows us to compare the aggregate investment outcomes for regions in which oil and gas activity started during the same year.

To perform the analysis, we define a new variable, *Options Ownership Concentration*, which resembles an option-ownership Herfindahl-Hirschman Index (HHI). Specifically,

$$\mathit{Options\ Ownership\ Concentration}_k = \sum_i \left(\frac{\mathit{Options}_i}{\mathit{Total\ Options}_k} \right)^2 \tag{5}$$

where i denotes firms that hold at least one option in the region, and k denotes a township.[26] The intuition behind our measure is that in regions with more dispersed options ownership,

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[26] This variable is measured during the last year in which a region is in our sample. However, our results are not sensitive to this timing decision and remain qualitatively similar using the time period's mean or median concentration, as well as using the region's concentration 12 months after the initial option is developed.

a greater share of the private information in the region is held by any of a firm's peers.[27]

The cross-sectional cut of the data leaves us a sample of 1,058 region observations. Table 7 displays the results. In our most stringent models, we include region cohort-year by county fixed effects. Such a strategy should soak up the majority of variation that may be related to the underlying asset value, as well as any differential development effects. However, we also control for the cumulative number of options available in the region. This is important, as it allows us to identify the effect of local ownership concentration on the number of options exercised after controlling for the number of options that are available to be drilled. Finally, we add controls for the region's average market value and drilling costs per well. We continue to cluster our standard errors at the county level.

The coefficients in Table 7 are each statistically significant at the 1% level. Further, they suggest that the economic magnitude of the effect is large. Model (3) implies that a one-standard-deviation decrease in options ownership concentration is related to a decrease of 0.74 options exercised per region. Given the unconditional sample average is 3.84 options exercised by the end of the sample, this represents a 19% decrease in total aggregate investment.

8 Robustness

Finally, to mitigate concerns regarding alternative mechanisms, and to confirm that our results reflect an investment delay due to the anticipation of peers' information spillover, we conduct six sets of robustness and subsample tests.

First, we refine our empirical specification to ensure the delays are due to *pure* learning incentives, and are not driven by projects with poor prospects. Formally, Proposition 4 of Chamley and Gale (1994) (i.e., $\delta W(\xi, h) > v(h) > 0$) indicates that these strategic

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[27] Our decision to work with the dispersion of information among firms instead of the the total number of options exercised by all firms in a geographic area is also to avoid a mechanical result in the regression. Indeed, the total number of options held in the region is likely to be mechanically related to the total number of options exercised.

considerations should affect projects that are deemed profitable in expectation even if they were exercised immediately ($v(h) > 0$). To implement this test, we use a subsample for which the measure of exercised peers' option quality, *Peers' Wells' Mkt. Value*, is greater than the sample median. This allows us to focus the analysis on options for which the underlying asset's potential is high. The results in Table 8 Panel A support our main findings, suggesting that our documented effect is the result of pure learning incentives, rather than that of poor project quality. In particular, both the economic and statistical significance of the subsample results are very similar to those in our main analysis (i.e., in Panel A of Table 8, the coefficient of interest in Model (3) is -0.031, compared to -0.037 in Table 2). In sum, it appears that firms delay the exercise of *valuable* projects in anticipation of information spillover from peer decisions and outcomes.

Second, a firm and its peers may attempt to coordinate their local drilling operations to generate positive externalities. For example, 97% of the drilling rigs (primary machinery required to drill wells) in the US are owned by intermediaries which specialize in drilling, requiring oil and gas firms to contract with them in order to complete their wells (Varco, 2020). While these machines can be moved within states using trucks and trains, there are related fixed costs that could be shared across multiple firms if they were to coordinate. More generally, a firm's incentive to wait on its peers could be driven by such coordination motives. To rule out this alternative explanation, we design a falsification test in which we alter the distance used to count the number of peers' option to be between 10 and 13 miles from the firm's option. The underlying assumption of this test is that a firm's benefits to coordinate with its peers still exist over such a small geographic range, but the relevance of the information obtained from wells located at that distance is limited (e.g., see figure 4). Table 8 Panel B reports the results of this falsification test. All three specifications reject such an explanation of our results.[28] In particular, each model shows coefficients on the falsified variable that are statistically indistinguishable from zero. Further, the economic

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[28] Table 8 Panel B also mitigates concerns of spurious results resulting from other mechanisms, such as aggregate oil and gas demand shocks.

magnitudes of the coefficients are trivial.

Third, it could be the case that we observe delays in regions with a large sets of peer options because of a local resource constraint. If all firms in an area request the service of local drillers at the same time, this could induce bottlenecks and mechanically delay option exercise. To mitigate this concern, we collect additional data on local rig utilization rates from the *Annual Rig Census*, produced by National Oilwell Varco (see Figure IA.2 in the Internet Appendix). These data provide us with time-varying state-level measures of the rig utilization rate. Then, we re-estimate the empirical models using a subsample that excludes periods during which local resources constraints are more likely to bind. To do this, we remove observations if the rig utilization rate is above 70%. Panel C of Table 8 reports the results of this test, which reject this alternative hypothesis.

Fourth, it may be more difficult for firms to acquire contiguous sections in regions with a greater number of peers. This may limit firms' ability to optimally exploit the land, by restricting how and where they perform drilling. Precisely, in some cases it can be optimal to drill wells that span multiple sections. In this sense, regions with a greater number of peers could produce less valuable wells, and thus induce delays from a classical real options perspective. To address this issue, we restrict our sample to options in which the first well has been drilled on only one section, effectively eliminating firms' ability to optimize drilling outside of the prescribed one-mile by one-mile section. Table 8 Panel D shows that our main result is unaffected.

Fifth, firms may self-select into specific regions based on multiple unobserved characteristics. To directly address this argument, we design additional Cox regression models that stratify by county-firm pairings. This is akin to using a county-firm fixed effect in a linear regression, and allows us to control for the relation of a particular firm with a given region in a very general way. Panel E of Table 8 presents the result of this additional specification and validates our main result.

Finally, oil and gas firms may engage in strategic alliances (SA) and joint ventures (JV) at some point during the exploration, production, or distribution processes (e.g., see Moskalev and Swensen, 2007; Rui et al., 2017). These arrangements foster information sharing among its members, and could thus challenge the validity of our design. Importantly, the existence of alliances is likely to bias our results upward, as firms would then have less incentive to wait on additional private information from their peers' options exercises. This argument suggests that our main results present an a upper bound for the economic magnitude of the effect. However, in an effort to eliminate this potential bias, we utilize the announcements of SAs and JVs from Thomson Reuters SDC Platinum to filter our main sample to a reduced sample with only firms that did not engage in such partnerships over the entire course of our sample. Internet Appendix Table IA.12 shows the results from this subsample (Panel A), and one in which we *also* drop all remaining private firms to guard against spotty private firm data coverage (Panel B), are of similar magnitude to those in Table 2.

9 Conclusion

In this paper we exploit detailed project-level data and arbitrary variation in the historical fragmentation of landownership rights to identify the causal impact of *potential* information spillover on corporate investment decisions. We find that each additional real option held by a firm's peers significantly influences the timing of the firm's own investment decisions, as the firm looks to reduce uncertainty and select superior projects by first observing its peers' decisions and outcomes. Although firms tend to trade off the costs of waiting with the benefits of acquiring additional information, the anticipation of information dampens investment at the aggregate level. Overall, we highlight novel learning incentives, even prior to information being released, that have important implications for the responsiveness of investment during and immediately following periods of heightened uncertainty.

References

Abadie, A., S. Athey, G. W. Imbens, and J. Wooldridge. 2017. When should you adjust standard errors for clustering? NBER working paper 24003.

Acemoglu, D., K. Bimpikis, and A. Ozdaglar. 2011. Experimentation, patents, and innovation. *American Economic Journal: Microeconomics* 3:37–77.

Aghamolla, C., and T. Hashimoto. 2020. Information arrival, delay, and clustering in financial markets with dynamic freeriding. *Journal of Financial Economics* 138:27–52.

Ai, C., and E. C. Norton. 2003. Interaction terms in logit and probit models. *Economics Letters* 80:123–129.

Alesina, A., and N. Fuchs-Schündeln. 2007. Good-bye Lenin (or not?): The effect of communism on people's preferences. *American Economic Review* 97:1507–1528.

Allen, D. W., and B. Leonard. 2021. Property right acquisition and path dependence: Nineteenth-century land policy and modern economic outcomes. *The Economic Journal* 131:3073–3102.

Allison, P. 2002. Bias in fixed-effects Cox regression with dummy variables. Working paper, University of Pennsylvania.

Bachmann, R., S. Elstner, and E. R. Sims. 2013. Uncertainty and economic activity: Evidence from business survey data. *American Economic Journal: Macroeconomics* 5:217–249.

Baker, S. R., N. Bloom, and S. J. Terry. 2020. Using disasters to estimate the impact of uncertainty. NBER Working Paper 27167.

Basu, S., and B. Bundick. 2017. Uncertainty shocks in a mmodel of effective demand. *Econometrica* 85:937–958.

Besley, T. 1995. Property rights and investment incentives: Theory and evidence from Ghana. *Journal of Political Economy* 103:903–937.

Bloom, N., M. Floetotto, N. Jaimovich, I. Saporta-Eksten, and S. J. Terry. 2018. Really uncertain business cycles. *Econometrica* 86:1031–1065.

Bloom, N., M. Schankerman, and J. V. Reenen. 2013. Identifying technology spillovers and product market rivalry. *Econometrica* 81:1347–1393.

Blum, J. 2019. Has the peak of the shale revolution come and gone? *Houston Chronicle* URL `https://www.houstonchronicle.com/business/energy/article/Has-the-peak-of-the-shale-revolution-come-and-14532327.php#:~:text=The%20shale%20boom%20really%20started,the%20Bakken%20also%20took%20off.`

Boddie, J. 2005. Behind Apple's strategy: Be second to market. URL `https://hbswk.hbs.edu/archive/behind-apple-s-strategy-be-second-to-market`.

Bustamante, M. C., and L. Frésard. 2020. Does firm investment respond to peers' investment? *Management Science* 67:4703–4724.

Caplin, A., and J. Leahy. 1994. Business as usual, market crashes, and wisdom after the fact. *American Economic Review* 84:548–565.

Chamley, C., and D. Gale. 1994. Information revelation and strategic delay in a model of investment. *Econometrica* 62:1065–1085.

Cho, H., and V. Muslu. 2021. How do firms change investments based on MD&A disclosures of peer firms? *The Accounting Review* 96:177–204.

Conley, T. G., and C. R. Udry. 2010. Learning about a new technology: Pineapple in Ghana. *American Economic Review* 100:35–69.

Covert, T. 2015. Experiential and social learning in firms: The case of hydraulic fracturing in the Bakken Shale. Working paper, University of Chicago.

Curry-Roper, J. M. 1987. 19th-centuryland law and current landownership patterns. *Geographical Review* 77:261–278.

Décaire, P. H. 2021. Capital budgeting and idiosyncratic risk. Working paper, Arizona State University.

Décaire, P. H., E. P. Gilje, and J. P. Taillard. 2020. Real option exercise: Empirical evidence. *Review of Financial Studies* 33:3250–3306.

Décaire, P. H., and D. Sosyura. 2021. CEO pet projects. Working paper, Arizona State University.

Demsetz, H. 1967. Toward a theory of property rights. *American Economic Review* 59:817–831.

Dixit, R. K., and R. S. Pindyck. 1994. *Investment under uncertainty.* Princeton University Press, Prinecton.

Fajgelbaum, P., E. Schaal, and M. Taschereau-Dumouch. 2017. Uncertainty traps. *Quarterly Journal of Economics* 132:1641–1692.

Fama, E. F., and K. R. French. 2002. The equity premium. *Journal of Finance* 57:637–659.

Foucault, T., and L. Frésard. 2014. Learning from peers' stock prices and corporate investment. *Journal of Financial Economics* 111:554–577.

Galiani, S., and E. Schargrodsky. 2010. Property rights for the poor: Effects of land titling. *Journal of Public Economics* 94:700–729.

Giglio, S., and K. Shue. 2014. No news is news: Do markets underreact to nothing? *Review of Financial Studies* 27:3389–3440.

Grenadier, S. R. 1996. The strategic exercise of options: Development cascades and overbuilding in real estate markets. *Journal of Finance* 51:1653–1679.

Grenadier, S. R. 1999. Information revelation through option exercise. *Review of Financial Studies* 12:95–129.

Grenadier, S. R. 2002. Option exercise games: An application to the equilibrium investment strategies of firms. *Review of Financial Studies* 15:691–721.

Grenadier, S. R., and A. Malenko. 2011. Real options signaling games with applications to corporate finance. *Review of Financial Studies* 24:3993–4036.

Grenadier, S. R., and N. Wang. 2005. Investment timing, agency, and information. *Journal of Financial Economics* 75:493–533.

Grennan, J. 2019. Dividend payments as a response to peer influence. *Journal of Financial Economics* 131:549–570.

Gul, F., and R. Lundholm. 1995. Endogenous timing and the clustering of agents' decisions. *Journal of Political Economy* 103:1039–1066.

Herrnstadt, E. M., R. Kellogg, and E. Lewis. 2020. The economics of time-limited development options: The case of oil and gas leases. NBER working paper 27165.

Hoberg, G., and G. Phillips. 2016. Text-based network industries and endogenous product differentiation. *Journal of Political Economy* 124:1423–1465.

Ilut, C. L., and M. Schneider. 2014. Ambiguous business cycles. *American Economic Review* 104:2368–2399.

Jaffe, A. B., M. Trajtenberg, and R. Henderson. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics* 108:577–598.

Jiang, W. 2017. Have instrumental variables brought us closer to the truth? *Review of Corporate Finance Studies* 6:127–140.

Jin, G. Z., M. Luca, and D. Martin. 2021. Is no news (perceived as) bad news? An experimental investigation of information disclosure. *American Economic Journal: Microeconomics* 13:141–73.

Kellogg, R. 2014. The effect of uncertainty on investment: Evidence from Texas oil drilling. *American Economic Review* 104:1698–1734.

Kopalek, M., J. Villar, J. Little, V. Spangler, S. Belcher, B. Brown, G. Long, and B. Mariner-Volpe. 2019. Natural gas annual. Tech. rep., U.S. Energy Information Administration.

Kopel, M., and C. Löffler. 2008. Commitment, first-mover-, and second-mover advantage. *Journal of Economics* 91:143–146.

Kruger, P., A. Landier, and D. Thesmar. 2015. The WACC fallacy: The real effects of using a unique discount rate. *Journal of Finance* 70:1253–1285.

Leary, M. T., and M. R. Roberts. 2005. Do firms rebalance their capital structures? *Journal of Finance* 60:2575–2619.

Leary, M. T., and M. R. Roberts. 2014. Do peer firms affect corporate financial policy? *Journal of Finance* 69:139–178.

Leonard, B., and D. P. Parker. 2021. Fragmented ownership and natural resource use: Evidence from the Bakken. *The Economic Journal* 131:1215–1249.

Libecap, G. D., and D. Lueck. 2011. The demarcation of land and the role of coordinating property institutions. *Journal of Political Economy* 119:426–467.

Mariotti, M. 1992. Unused innnovations. *Economics Letters* 38:367–371.

Moskalev, S. A., and R. B. Swensen. 2007. Joint ventures around the globe from 1990–2000: Forms, types, industries, countries and ownership patterns. *Review of Financial Economics* 16:29–67.

Nieuwerburgh, S. V., and L. Veldkamp. 2006. Learning asymmetries in real business cycles. *Journal of Monetary Economics* 53:753–772.

Novy-Marx, R. 2007. An equilibrium model of investment under uncertainty. *Review of Financial Studies* 20:1461–1502.

Petersen, M. A. 2009. Estimating standard errors in finance panel data sets: Comparing approaches. *Review of Financial Studies* 22:435–480.

Porter, M. E. 2008. *On Competition, Updated and Expanded Edition.* Boston: Harvard Business Press Books.

Reuters. 2017. Volkswagen is 'second mover' in electric commercial vehicles: executive. URL https://www.reuters.com/article/us-volkswagen-electric/volkswagen-is-second-mover-in-electric-commercial-vehicles-executive-idUSKCN1BS0GT.

Rob, R. 1991. Learning and capacity expansion under demand uncertainty. *Review of Economic Studies* 58:655–675.

Rui, Z., F. Peng, K. Ling, H. Chang, G. Chen, and X. Zhou. 2017. Investigation into the performance of oil and gas projects. *Journal of Natural Gas Science and Engineering* 38:12–20.

Staiger, D., and J. Stock. 1997. Instrumental variables regression with weak instruments. *Econometrica* 65:557–586.

Stock, J. H., and M. Yogo. 2005. *Testing for weak instruments in linear IV regression.* Cambridge University Press.

Tchetgen Tchetgen, E. J. T., S. Walter, S. Vansteelandt, T. Martinussen, and M. Glymour. 2015. Instrumental variable estimation in a survival context. *Epidemiology* 26:402–410.

Tran, V. D., D. S. Sibley, and S. Wilkie. 2012. Second mover advantage and entry timing. *Journal of Industrial Economics* 60:517–535.

Tufano, P. 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. *Journal of Finance* 51:1097–1137.

Varco, N. O. 2020. NOV 67th annual rig census. *Drilling Contractor Magazine* URL `https://www.nov.com/-/media/nov/files/about/news/novs-67th-annual-rig-census/drilling-contractor-nov-67th-annual-rig-census-november-december-2020.pdf?la=en-us&hash=E1418C1292250212E99E46350E28177C`. Accessed: 2021-11-11.

Veldkamp, L. L. 2005. Slow boom, sudden crash. *Journal of Economic Theory* 124:230–257.

Whited, T. M. 2006. External finance constraints and the intertemporal pattern of intermittent investment. *Journal of Financial Economics* 81:467–502.

Wittry, M. D. 2021. (Debt) overhang: Evidence from resource extraction. *Review of Financial Studies* 34:1699–1746.

Zhang, J. 1997. Strategic delay and the onset of investment cascades. *RAND Journal of Economics* 28:188–205.

Figure 1: Historical Landowners Per Township and Peers' Options This graph plots the relationship between the historical number of landowners and the number of peers' options by township averaged for each interval. The dotted line presents the fitted relation. The histogram shows the distribution of the number of historical landowners for each interval. The range of values for the historical landowner variable used in this graph corresponds to the 1^{st} through 99^{th} percentiles of the distribution.

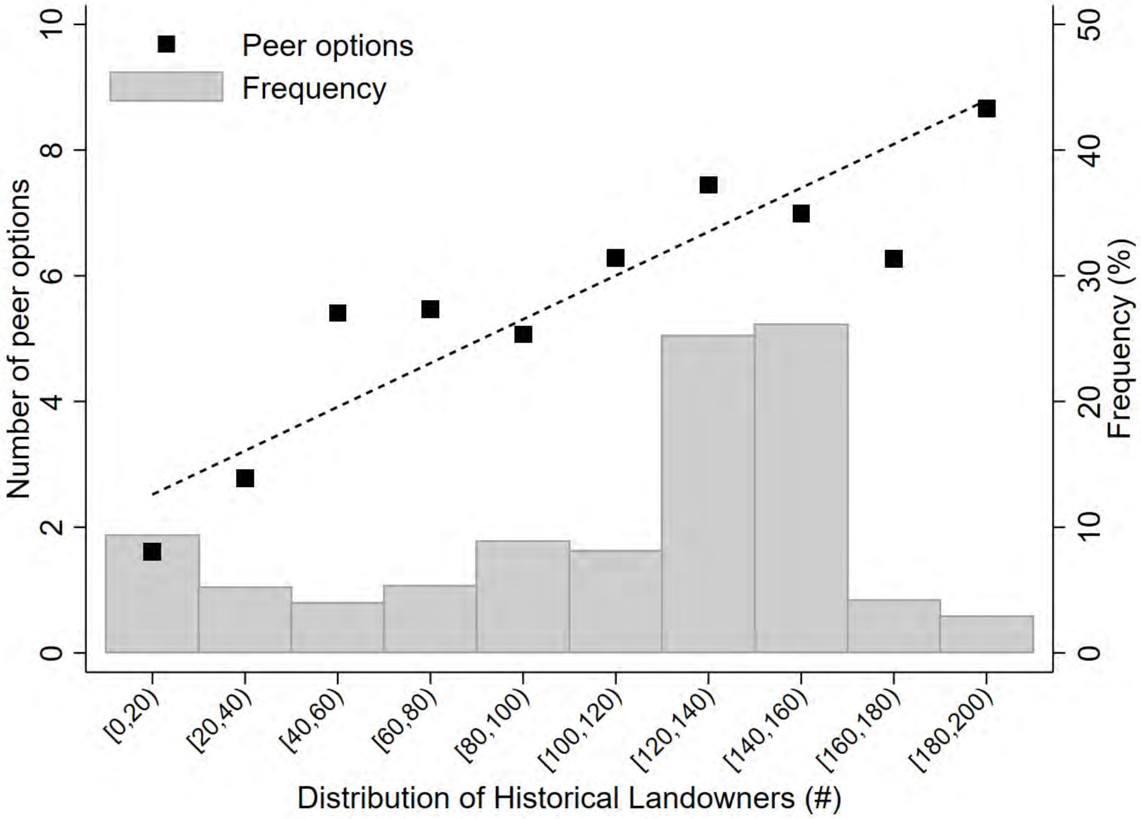


Figure 2: Louisiana and Oklahoma Institutional Features. This figure shows how land surveying methods, and land spacing requirements differs across states. The land survey method in Louisiana and Oklahoma, in contrast to Texas for example, was conducted using the rectangular survey system. This is reflected in this picture by having 36 standardized 1 miles by 1 miles sections per township. This provides us with a well define land unit in the analysis. Further, all states have different spacing requirements for horizontal wells (i.e., the minimum amount of acres to be acquired by a firm to drill a well). Conveniently, Louisiana and Oklahoma both require oil and gas companies to acquire the leasing rights to 640 acres, or the size of a section, to begin drilling activities. Combined, these features provide us with a clean unit of measurement for the real options in our sample.

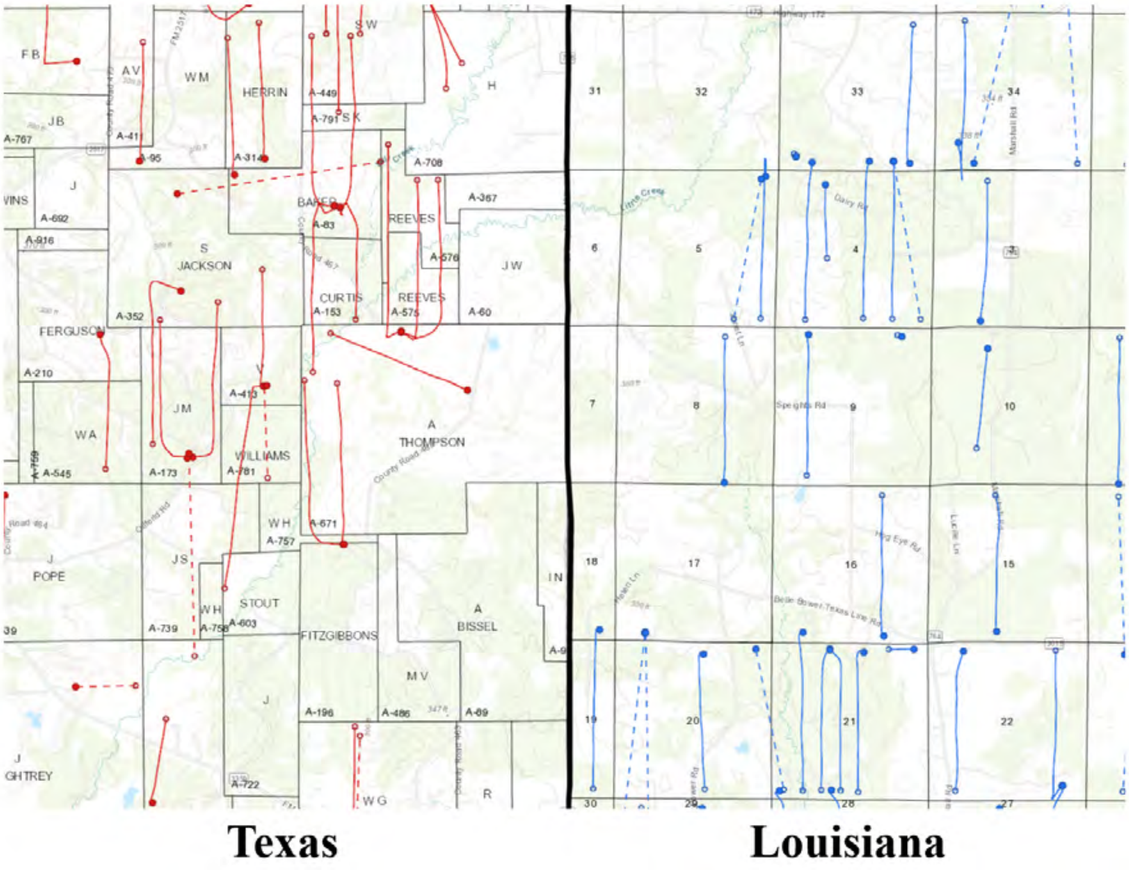


Figure 3: Sections, Options, and Identifying Peers' Available Options. This figure displays the intuition of the construction of our main variable of interest, *Unexercised Investment Opportunities (Peers)*. Each blue dot depicts a well dug by the firm in question, while each yellow dot represents a well dug by the firm's peers. Point (A) identifies a section, a one mile by one mile square of land. Point (B) shows that for an available option held by a peer to be counted in our variable of interest (*Unexercised Investment Opportunities*), it must be located within 3 miles from the option in our main specification. Thus, for a section to be considered a peers' option for the firm option highlighted in red, it must be located within the outer blue line and have an initial well dug (e.g., one yellow dot). In the current example, there would be 21 available peer options the firm could learn from when they get exercised. Point (C) shows that available options are held-by-production, a section on which the first well has been completed, but no infill wells have been drilled. Point (D) identifies sections on which the option has been exercised (i.e., the infill well has been drilled).

Figure 4: Correlation of Well's Drilling Outcomes as a Function of Distance. This figure displays the correlation between wells' drilling outcomes measured in barrel of oil equivalent (BOE) as a function of the distance between a pair of wells. For each distance, we measure the pairwise correlation between the wells in our sample and any other wells that are located within the distance considered on the x-axis. The grey shaded area represents the distance used in our main definition of a firm's peers (0-3 miles), while the red shaded area represents the definition of a firm's peers used in our falsification analysis (10-13 miles). A barrel-of-oil equivalent is a standardized unit of measurement to compare oil and gas production, where six thousand cubic feet (mcf) of natural gas is equal to one barrel of oil.

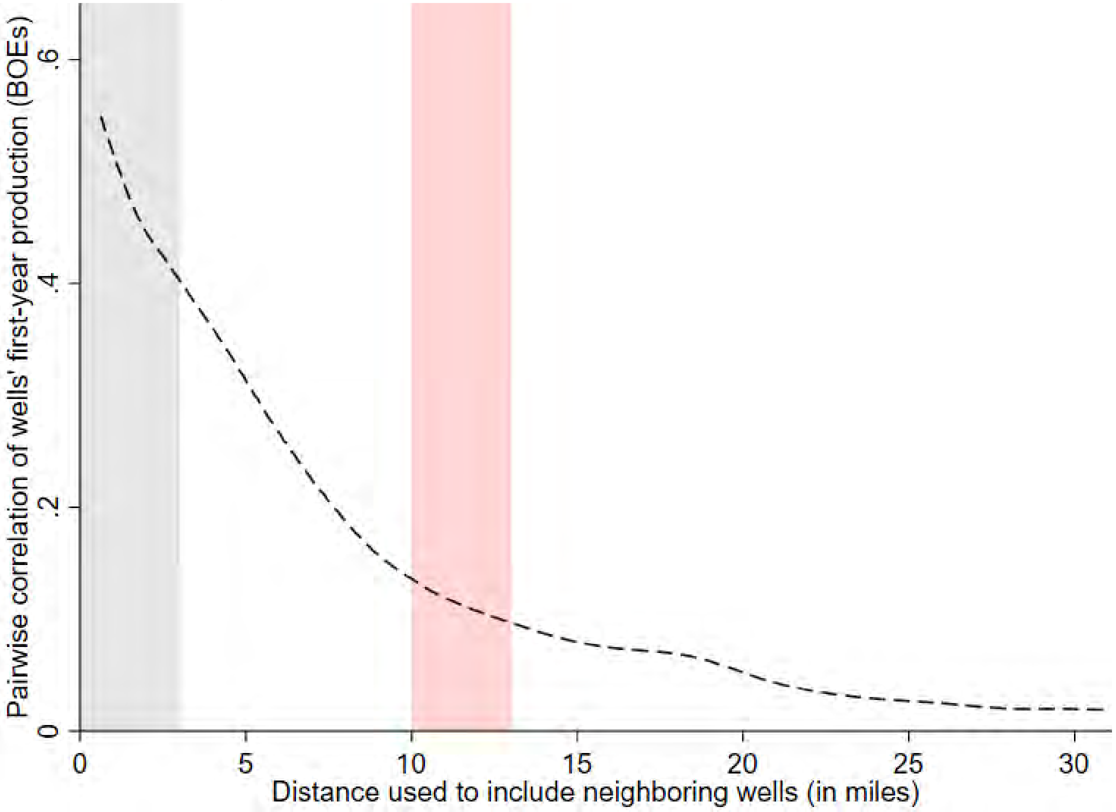
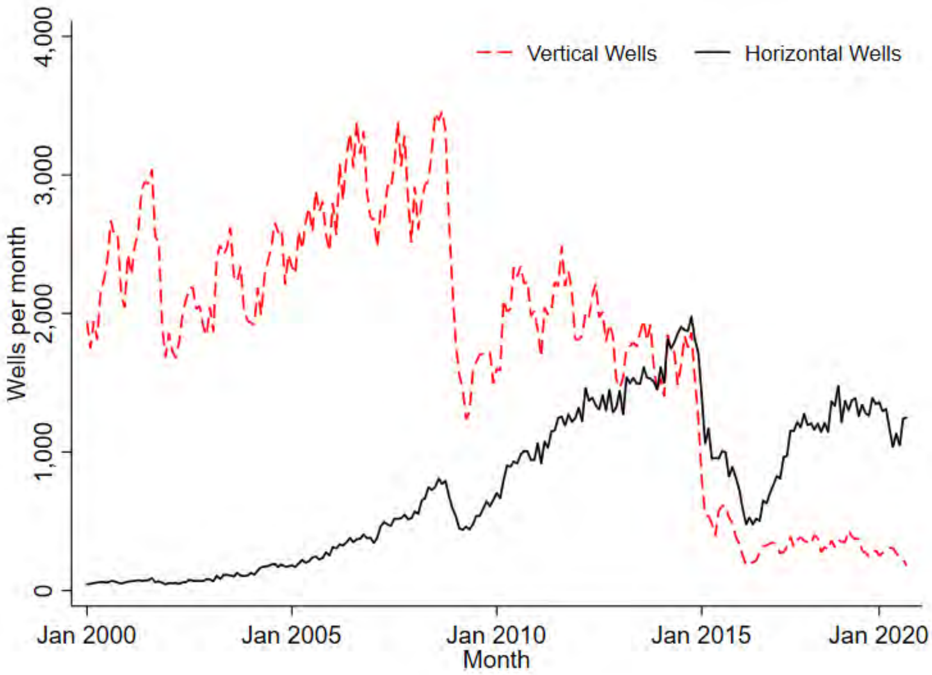


Figure 5: Chronology of Oil and Gas Development. This figure depicts the development of drilling technology used for Oklahoma and Louisiana (Panel A), and the historical oil and gas production for Oklahoma (Panel B). Panel A displays the number of wells drilled for the vertical and horizontal drilling technology on the period 2000 to 2020. The red and blue lines respectively indicate the number of horizontal and vertical wells drilled in a given month. Panel B displays the number of barrels produced per day in the state of Oklahoma, for the period 1900 to 2000. Sources: Claxton, Larry (ed.), 2001, Oil and gas information: Oklahoma Corporation Commission Web site: `http://www.occ.state.ok.us/text_files/o&gfiles.htm` (B).

(A) Evolution of the Drilling Technology Used for Oil and Gas Wells.



(B) Historical Oil and Gas Production in the State of Oklahoma.

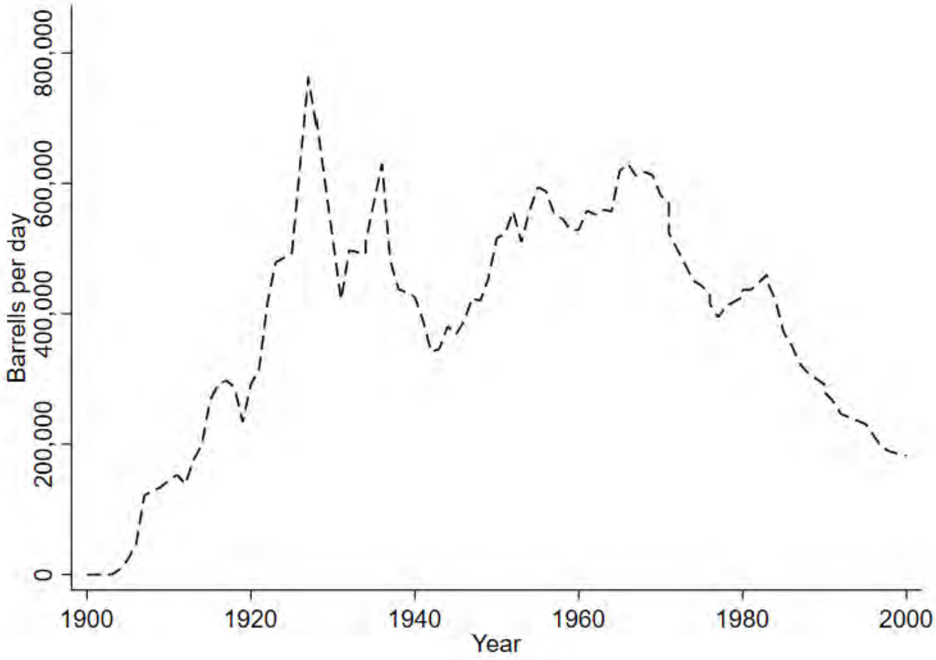


Figure 6: Peer Options and Project Exercise. This figure plots the survival function, measured by the proportion of infill drilling options that remain unexercised (i.e. that have "survived') over our sample period from 2005 through 2020. The *No Peer Options* line represents the survival function for the subset of options that did not have any peer options located within 3 miles during the full life of the option. The *At Least One Peer Option* line represents the survival function for the subset of options that had at least one peer option located within 3 miles at any point during life of the option.

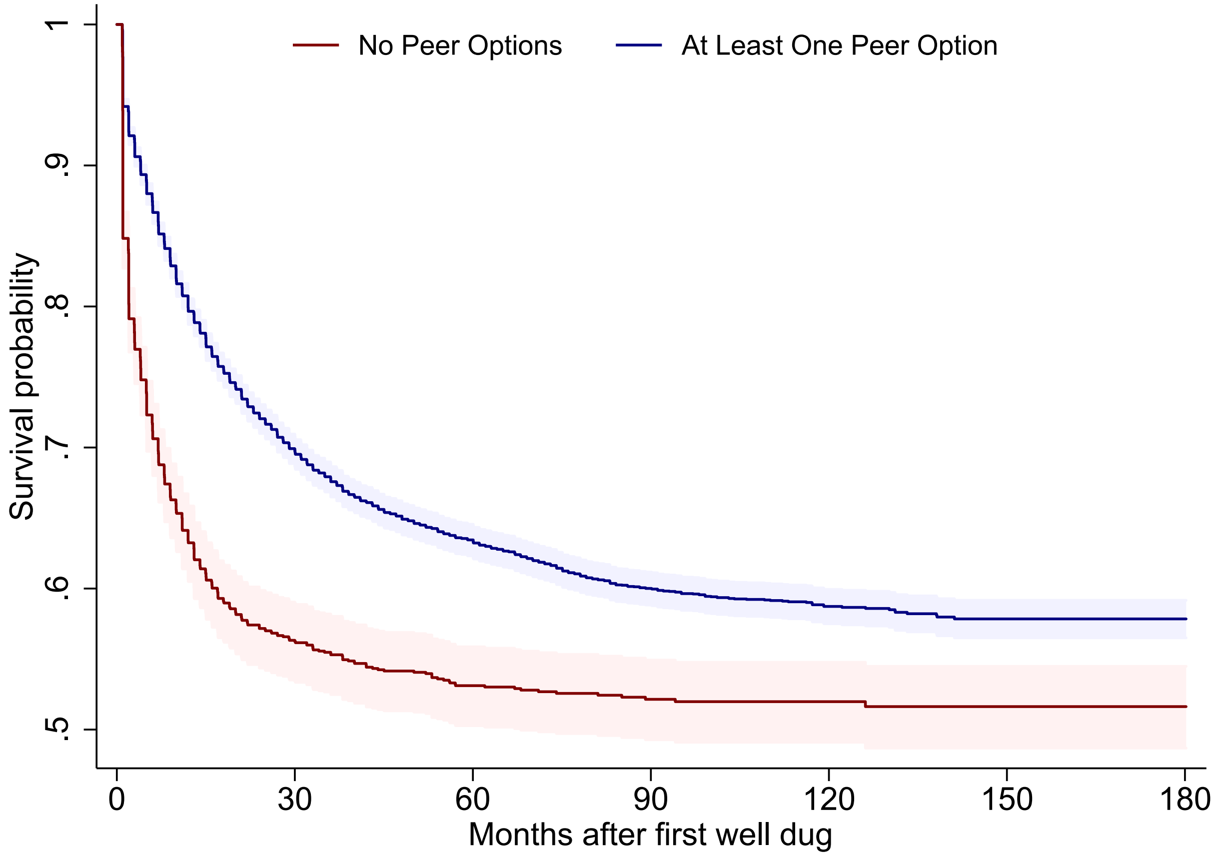
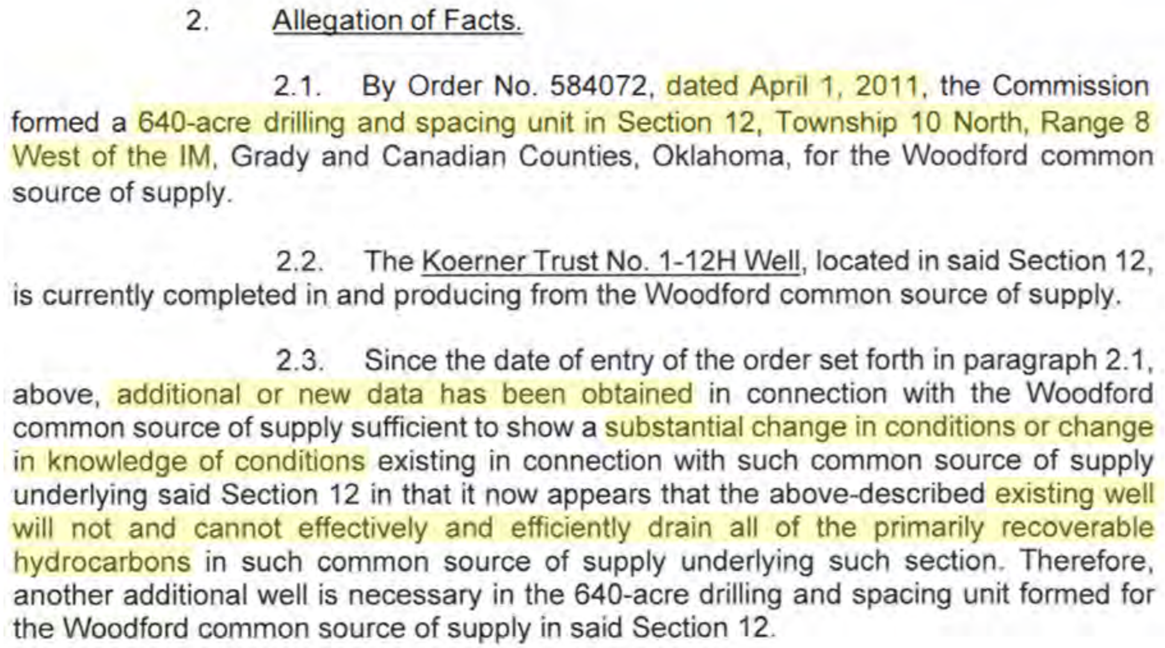


Figure 7: Increased Density and New Information This figure presents an excerpt from an *Increased Density* request made by the exploration firm *Camino Natural Resources, LLC* to the Oklahoma Corporation Commission. Firms are required to obtain regulatory approval before drilling additional infill wells on their plot of land, and they must provide motivating arguments explaining why adding infill wells is justified (highlighted in yellow). **Source**: Oklahoma Corporate Commission (2021), cause CD No. 202101827.



2. Allegation of Facts.

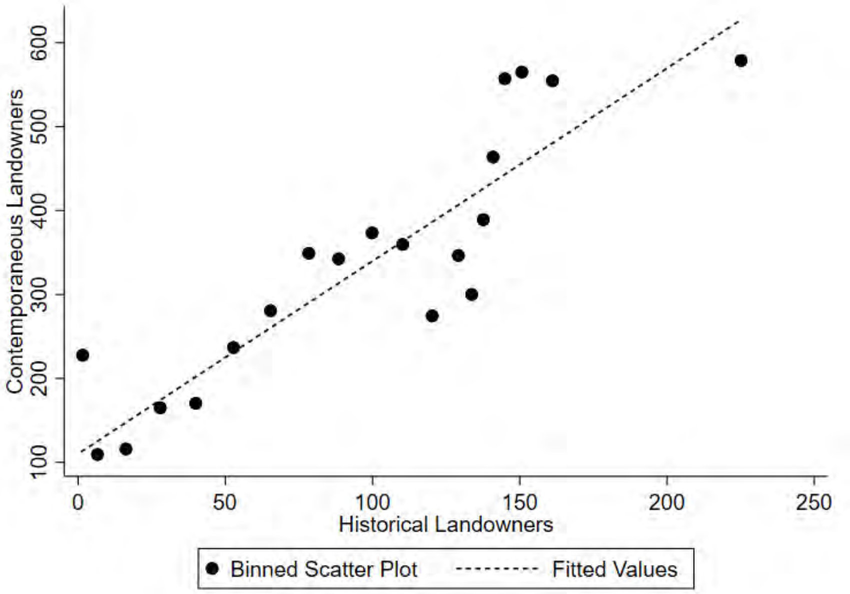
2.1. By Order No. 584072, dated April 1, 2011, the Commission formed a 640-acre drilling and spacing unit in Section 12, Township 10 North, Range 8 West of the IM, Grady and Canadian Counties, Oklahoma, for the Woodford common source of supply.

2.2. The Koerner Trust No. 1-12H Well, located in said Section 12, is currently completed in and producing from the Woodford common source of supply.

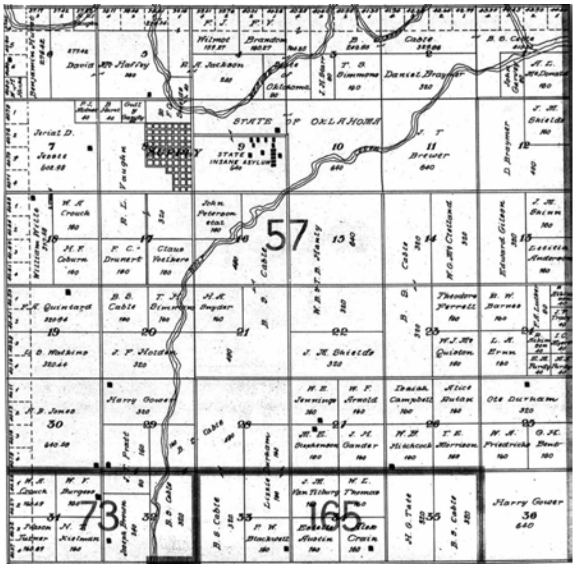
2.3. Since the date of entry of the order set forth in paragraph 2.1, above, additional or new data has been obtained in connection with the Woodford common source of supply sufficient to show a substantial change in conditions or change in knowledge of conditions existing in connection with such common source of supply underlying said Section 12 in that it now appears that the above-described existing well will not and cannot effectively and efficiently drain all of the primarily recoverable hydrocarbons in such common source of supply underlying such section. Therefore, another additional well is necessary in the 640-acre drilling and spacing unit formed for the Woodford common source of supply in said Section 12.

Figure 8: Instrumental Variable Construction and Intuition. Figure (A) presents the correlation between the number of historical and contemporaneous landowners in our sample. To mitigate the effect of outliers, each is winsorized at the 1% and 99% levels. Figures (B) and (C) present distinctive examples of how individual property ownership can fragment the land. The figures are from two townships in Woodward County, Oklahoma in 1910. In Figure (B), the total number of historical (contemporaneous) landowners in the 3 miles by 3 miles region is equal to 76 (324), while in Figure (C), there is a total of 124 (383) landowners for a region of similar size. The more sections a specific owner controls, the easier it becomes for oil and gas companies to collect the drilling rights to multiple contiguous plots of land before competitors frustrate their efforts. Source Information: Ancestry.com. U.S., Indexed County Land Ownership Maps, 1860-1918.

(A) Landowners Through Time. This figure presents the correlation between the number of historical landowners in townships and the number of contemporaneous landowners at the time the mineral rights leases are acquired in our sample.



(B) Low Historical Landownership Fragmentation. This figure presents the historical landownership fragmentation of the township 24N-12W, Oklahoma.



(C) High Historical Landownership Fragmentation. This figure presents the historical landownership fragmentation of the township 21N-18W, Oklahoma.

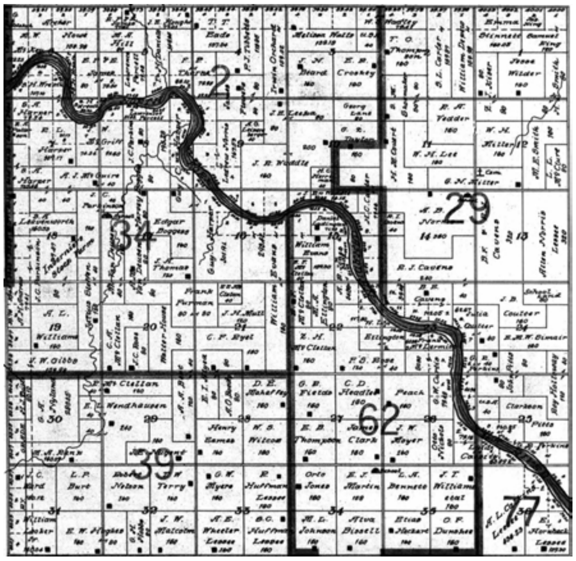


Table 1: Summary Statistics. This table reports the summary statistics. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. *Peers' Wells' Value*, *Mean Distance Between Options*, *First Well's Market Value*, and *Drilling Costs* are reported in their unlogged form. *Historical Landowners Fragmentation* and *Contemporaneous Landowners Fragmentation* are measured at the township level. All variables are defined in Internet Appendix Table IA.2.

Panel A: Data Description

	Total Distinct Real Options	Total Distinct Firms
Full Sample	8,725	442
Public Firms	5,892	63
Private Firms	2,833	379

Panel B: Summary Statistics

	Mean	25th Pct.	Median	75th Pct.	Std. Dev.	No. Obs.
Regional Variables						
Unexercised Investment Opportunities (Peers)$_{j,t}$	3.95	1.00	3.00	6.00	3.66	537,093
Cumulative Number of Wells Drilled$_{j,t}$	17.35	8.00	17.00	25.00	11.05	537,093
Unexercised Investment Opportunities (Own)$_{j,t}$	4.89	2.00	4.00	7.00	3.96	537,093
Peers' Wells' Value$_{j,t}$ ($Ms)	3.19	1.24	2.42	4.56	2.72	537,093
Royalty Rate$_{k}$ (%)	21.08	18.70	19.15	20.25	6.31	1,054
Firm Level Variables						
Firm Drilling Activity$_{i,t}$ (Annual)	0.76	0.00	0.00	0.00	3.88	4,538
Mean Distance Between Options$_{i,t}$ (Miles)	142.44	33.29	103.41	217.67	134.07	537,093
Portfolio Concentration$_{i,k,t}$	0.37	0.12	0.25	0.52	0.31	537,093
Total Number of Options Per Firm$_{i}$	19.45	1.00	3.00	11.00	82.68	442
Well Level Variables						
First Well's Market Value$_{j,t}$ ($Ms)	3.19	0.79	2.01	4.54	3.61	537,093
Drilling Cost$_{j,t}$ ($Ms)	4.23	3.46	4.51	5.06	1.95	537,093
Well Lateral Length$_{j,t}$ (1,000 ft.)	4.36	3.67	4.71	4.95	1.94	537,093
Oil-to-Gas Ratio$_{j}$	0.30	0.00	0.14	0.58	0.34	537,093
Financial Market Variables						
18-Month Oil Futures Price$_{t}$	69.46	53.09	62.74	88.36	18.97	537,093
18-Month Oil Futures Implied Volatility$_{t}$ (%)	26.44	23.13	26.95	30.57	5.33	537,093
10-Year Risk Free Rate$_{t}$(%)	2.45	1.97	2.35	2.81	0.64	537,093
Cost of Equity$_{i,t}$ (%)	9.39	7.73	8.83	10.64	2.27	273,427
Landownership Variables						
Historical Landowners Fragmentation$_{k}$	94.74	45.00	105.00	139.00	55.56	2,046
Contemporaneous Landowners Fragmentation$_{k}$	327.65	45.00	203.00	460.00	386.44	2,046

Table 2: Peer Options and Project Exercise. This table reports the results of Cox survival models in which the failure event is the drilling of a section's infill well (the exercise of the section's real option). The sample includes section-month observations over the period of 2005 through 2020. The main independent variable of interest is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.030***	-2.93	-0.037***	-3.65	-0.037***	-3.62
	(0.011)		(0.011)		(0.010)	
Cumulative Number of Wells Drilled$_{j,t}$	0.053***	5.41	0.048***	4.95	0.050***	5.18
	(0.004)		(0.004)		(0.004)	
Unexercised Investment Opportunities (Own)$_{j,t}$	-0.035***	-3.47	-0.043***	-4.23	-0.051***	-4.99
	(0.011)		(0.011)		(0.010)	
Portfolio Concentration$_{i,t}$	0.188	20.72	0.096	10.06	0.076	7.94
	(0.181)		(0.179)		(0.168)	
Mean Distance Between Options$_{i,t}$	-0.059	-5.75	-0.067*	-6.46	-0.074**	-7.17
	(0.037)		(0.035)		(0.034)	
Firm Skill Level$_{i,t}$	-0.032	-3.14	-0.237***	-21.06	-0.192**	-17.48
	(0.057)		(0.083)		(0.083)	
Royalty Rate$_{k}$ (%)	0.007	0.69	0.007	0.67	0.006	0.58
	(0.007)		(0.007)		(0.007)	
Well Lateral Length$_{j,t}$ (1,000 ft.)			-0.047**	-4.56	-0.012	-1.22
			(0.023)		(0.020)	
First Well's Market Value$_{j,t}$			0.233***	26.21	0.207***	23.00
			(0.068)		(0.061)	
Peers' Wells' Mkt. Value$_{j,t}$			0.063***	6.48	0.058***	5.97
			(0.015)		(0.014)	
Oil-to-Gas Ratio$_{j}$			0.308**	36.03	0.340***	40.51
			(0.133)		(0.124)	
Drilling Cost$_{j,t}$			-0.019	-1.90	-0.039	-3.84
			(0.042)		(0.030)	
Futures Price$_{t}$					0.009***	0.90
					(0.003)	
Implied Volatility$_{t}$ (%)					-0.022***	-2.15
					(0.007)	
10-Year Risk Free Rate$_{t}$ (%)					0.176***	19.27
					(0.057)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-17,286		-17,174		-17,074	
Wald Chi^2	398		541		1,105	
Observations	537,093		537,093		537,093	

Table 3: The Dynamics of the Costs vs. Benefits Tradeoff. This table reports the results of Cox survival models in which the failure event is the drilling of a section's infill well (the exercise of the section's real option). The sample includes section-month observations over the period of 2005 through 2020. The main independent variable of interest is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. This table also investigates the impact of firms' cost of equity capital (Panel A) and the signal of project quality firms receive from their peers (Panel B). Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Panel A: Firm-level Discount Rates						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.095**	-9.07	-0.107***	-10.14	-0.115***	-10.83
	(0.038)		(0.038)		(0.038)	
Unexercised Inv. Opp. (Peers)$_{j,t}\times$ Cost of Equity$_{i,t}$	0.007*	0.68	0.008**	0.77	0.009**	0.86
	(0.004)		(0.004)		(0.004)	
Cost of Equity$_{i,t}$ (%)	-0.049**	-4.74	-0.065***	-6.25	-0.069***	-6.69
	(0.023)		(0.024)		(0.026)	
$Pseudo-Loglikelihood$	-7,033		-6,981		-6,943	
Wald Chi^2	532		671		1,390	
Observations	273,427		273,427		273,427	
Panel B: Signal of Project Quality						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-1.106***	-66.91	-0.980***	-62.49	-0.816***	-55.77
	(0.158)		(0.145)		(0.141)	
Unexercised Inv. Opp. (Peers)$_{j,t}$ × Peers' Wells' Mkt. Value$_{j,t}$	0.071***	7.31	0.062***	6.41	0.051***	5.27
	(0.011)		(0.010)		(0.009)	
Peers' Wells' Mkt. Value$_{j,t}$	0.062***	6.42	0.058***	5.92	0.054***	5.54
	(0.015)		(0.013)		(0.013)	
$Pseudo-Loglikelihood$	-17,194		-17,132		-17,046	
Wald Chi^2	775		884		1,636	
Observations	537,093		537,093		537,093	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	

Table 4: The Relevance of Information Sources. This table reports the results of Cox survival models in which the failure event is the drilling of a section's infill well (the exercise of the section's real option). The sample includes section-month observations over the period of 2005 through 2020. The main independent variable of interest is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. This table also investigates the impact of project similarity of peer options on project exercise (Panel A), and the impact of peer quality on project exercise (Panel B). In Panel A, *Unexercised Investment Opportunities (Same Resource)* measures all peer options (within 3 miles) that have the same majority (> 50%) resource (oil or gas) as the option in question, while *Unexercised Investment Opportunities (Different Resource)* measures all peer options (within 3 miles) that have a different majority resource as the option in question. In Panel B, *Unexercised Investment Opportunities (High-Skill Peers)* measures all options (within 3 miles) held by firms whose mean well produces an above-sample-median quantity of oil or gas, while *Unexercised Investment Opportunities (Low-Skill Peers)* measures all options (within 3 miles) held by firms whose mean well produces a below-sample-median quantity of oil or gas. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Panel A: Project Similarity						
Unexercised Investment Opportunities (Same Resource)$_{j,t}$	-0.112***	-10.60	-0.136***	-12.75	-0.138***	-12.87
	(0.035)		(0.034)		(0.032)	
Unexercised Investment Opportunities (Different Resource)$_{j,t}$	-0.026	-2.58	-0.040	-3.91	-0.036	-3.49
	(0.025)		(0.027)		(0.025)	
Chi^2 (Same Resource—Different Resource)	8.25***		17.25***		15.90***	
(p-Value)	(0.004)		(0.000)		(0.000)	
$Pseudo-Loglikelihood$	-17,285		-17,174		-17,074	
Wald Chi^2	474		563		1,161	
Panel B: Quality of Peers						
Unexercised Investment Opportunities (High-Skill Peers)$_{j,t}$	-0.125***	-11.77	-0.154***	-14.23	-0.148***	-13.79
	(0.041)		(0.044)		(0.040)	
Unexercised Investment Opportunities (Low-Skill Peers)$_{j,t}$	0.026	2.65	0.021	2.16	0.007	0.70
	(0.024)		(0.024)		(0.024)	
Chi^2 (High Skill—Low Skill)	11.40***		12.54***		11.94***	
(p-Value)	(0.001)		(0.000)		(0.001)	
$Pseudo-Loglikelihood$	-17,280		-17,168		-17,071	
Wald Chi^2	435		580		1,254	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	
County Strata	Yes		Yes		Yes	
Observations	537,093		537,093		537,093	

Table 5: Two-Stage (Linear-Cox) Instrumental Variables Results. This table reports the results of two-stage instrumental variable Cox survival models in which the failure event is the drilling of a section's infill well (the exercise of the section's real option). The sample includes section-month observations over the period of 2005 through 2020. Panel A displays the linear first-stage results. The dependent variable is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. The main independent variable of interest is *Historical Landownership Fragmentation*, which is equal to the number of landowners per available section located within 3 miles of the section of interest. Panel B reports the second-stage instrumented Cox regression results. The main independent variable is *Instrumented Unexercised Investment Opportunities (Peers)*, which is equal to the fitted values from the linear first-stage regressions in Panel A. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. Finally, data on historical landownership use in the first-stage regressions in Panel A are from the Bureau of Land Management (BLM). All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. In Panel B, the clustered standard errors are generated using a bootstrapping procedure with 500 iterations. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Panel A: First Stage Results

Dependent variable =	Unexercised Investment Opportunities (Peers)$_{j,t}$		
	(1)	(2)	(3)
Historical Landowners Fragmentation$_{j,t}$	0.011***	0.011***	0.011***
	(0.003)	(0.003)	(0.003)
Controls	Yes	Yes	Yes
County FE	Yes	Yes	Yes
KP F-statistic	10.9	11.6	12.1
Observations	414,176	414,176	414,176
R^2	0.47	0.48	0.48

Panel B: Second Stage Results

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Instrumented Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.262**	-23.02	-0.253**	-22.39	-0.249**	-22.02
	(0.120)		(0.114)		(0.113)	
Cumulative Number of Wells Drilled$_{j,t}$	0.092***	9.65	0.083***	8.66	0.087***	9.05
	(0.024)		(0.023)		(0.023)	
Unexercised Investment Opportunities (Own)$_{j,t}$	-0.120***	-11.35	-0.123***	-11.60	-0.132***	-12.37
	(0.045)		(0.044)		(0.044)	
Portfolio Concentration$_{i,t}$	-0.042	-4.13	-0.201	-18.24	-0.239	-21.24
	(0.215)		(0.230)		(0.203)	
Mean Distance Between Options$_{i,t}$	-0.141**	-13.16	-0.160***	-14.79	-0.172***	-15.82
	(0.056)		(0.057)		(0.054)	
Firm Skill Level$_{i,t}$	0.061	6.25	-0.167	-15.35	-0.107	-10.17
	(0.087)		(0.111)		(0.115)	
Royalty Rate$_k$ (%)	0.011	1.15	0.011	1.08	0.010	0.96
	(0.009)		(0.008)		(0.009)	
Well Lateral Length$_{j,t}$ (1,000 ft.)			-0.091***	-8.73	-0.037	-3.60
			(0.028)		(0.027)	
First Well's Market Value$_{j,t}$			0.261***	29.78	0.224***	25.16
			(0.080)		(0.073)	
Peers' Wells' Mkt. Value$_{j,t}$			0.089***	9.35	0.084***	8.75
			(0.020)		(0.020)	
Oil-to-Gas Ratio$_j$			0.295**	34.26	0.340***	40.53
			(0.144)		(0.125)	
Drilling Cost$_{j,t}$			0.051	5.19	-0.003	-0.33
			(0.045)		(0.032)	
Futures Price$_t$					0.015***	1.48
					(0.003)	
Implied Volatility$_t$ (%)					-0.015**	-1.47
					(0.007)	
10-Year Risk Free Rate$_t$ (%)					0.121	12.83
					(0.078)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-13,651		-13,564		-13,481	
Wald Chi^2	84		112		190	
Observations	414,176		414,176		414,176	

Table 6: Direction of Bias and Internal Validity of the Instrumental Variable. This table reports the results of linear regression models that investigate the relationship between land grant type and underlying asset quality (Panel A), the internal validity of our instrumental variable (Panel B), and the direction of the omitted varaiables bias from our reduced form Cox models (Panel C). The sample includes section observations for exercised options over the period of 2005 through 2020. In both panels, the dependent variable is the natural log of the market value of a section's first well. In Panel A, the independent variable of interest is *Fraction Cash-Entry Grants*, which measures the fraction of total grants in the township that are cash-entry. In panel B, the independent variable of interest is *Landowners Fragmentation*, which measures the natural log of of the number of landowners per available section located within 3 miles of the section of interest. Finally, in Panel C, the independent variable interest is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. The control variables used in Model (2) of both panels are the same as those in Model (3) of Table 2. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. Finally, data on historical landownership use in the regressions in Panel A are from the Bureau of Land Management (BLM). All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Panel A: Effect of Land Grant Type

Dependent variable =	log(First Well's Market Value$_j$)	
	(1)	(2)
Fraction Cash-Entry Grants$_j$	0.032	0.094
	(0.210)	(0.155)
Controls	No	Yes
County FE	Yes	Yes
Observations	7,304	7,304
R^2	0.29	0.42

Panel B: Internal Validity

Dependent variable =	log(First Well's Market Value$_j$)	
	(1)	(2)
Historical Landowners Fragmentation$_j$	-0.000	0.000
	(0.001)	(0.001)
Controls	No	Yes
County FE	Yes	Yes
Observations	6,944	6,944
R^2	0.30	0.42

Panel C: Direction of Bias

Dependent variable =	log(First Well's Market Value$_j$)	
	(1)	(2)
Unexercised Investment Opportunities (Peers)$_j$	0.040***	0.015*
	(0.009)	(0.008)
Controls	No	Yes
County FE	Yes	Yes
Observations	8,718	8,718
R^2	0.33	0.47

Table 7: Option Ownership Concentration and Total Regional Investment. This table reports the results of cross-sectional linear regression models in which the dependent variable is total investment in a region by the end of our sample period. The main independent variable of interest is *Options Ownership Concentration*, which is akin to an option-ownership HHI. The models progressively add fixed effects, and because singletons are dropped, the sample size is reduced to 1,044 region observations in Model (2) and 767 region observations in Model (3). Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Dependent variable =	Total Regional Investment$_k$		
	(1)	(2)	(3)
Options Ownership Concentration$_k$	2.025***	1.751***	1.741***
	(0.253)	(0.239)	(0.370)
Cumulative Number of Options Available$_k$	0.620***	0.636***	0.649***
	(0.030)	(0.029)	(0.031)
Average Well's Market Value$_k$	-0.213***	-0.014	-0.035
	(0.070)	(0.089)	(0.130)
Average Drilling Cost$_k$	0.001	-0.059	-0.059
	(0.045)	(0.048)	(0.050)
Region Cohort-Year FE	Yes	Yes	No
County FE	No	Yes	No
Region Cohort-Year × County FE	No	No	Yes
Observations	1,058	1,044	772
R^2	0.78	0.82	0.85

Table 8: Robustness Tests and Alternative Explanations. This table reports the results of Cox survival models in which the failure event is the drilling of a section's infill well (the exercise of the section's real option). This table considers a number of alternative explanations for our main results and provides five robustness tests. The main independent variable of interest in Panels A, and C throud E is *Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 3 miles of the section of interest. In Panel B, the main independent variable of interest is *Falsified Unexercised Investment Opportunities (Peers)*, which is equal to the number of real options held by a firm's peers and located within 10-13 miles of the section of interest. Data on horizontal wells are from DrillingInfo, while data for the remaining covariates are taken from Bloomberg, St. Louis Federal Reserve Bank, and publicly available firm reports. All variables are defined in Internet Appendix Table IA.2. Robust standard errors, clustered at the county level, are reported in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

	Hazard Model for Project Exercise					
	(1)		(2)		(3)	
	Estimates	HI(%)	Estimates	HI(%)	Estimates	HI(%)
Panel A: Subsample of Valuable Projects						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.029**	-2.86	-0.029**	-2.90	-0.031**	-3.04
	(0.013)		(0.014)		(0.012)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-11,014		-10,897		-10,860	
Wald Chi^2	272		892		1,306	
Observations	268,547		268,547		268,547	
Panel B: Falsification Test						
Falsified Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.002	-0.20	-0.003	-0.28	-0.001	-0.11
	(0.003)		(0.003)		(0.002)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-17,296		-17,190		-17,091	
Wald Chi^2	461		527		1,257	
Observations	537,093		537,093		537,093	
Panel C: Rig Utilization Test						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.026**	-2.52	-0.031**	-3.03	-0.033***	-3.29
	(0.012)		(0.012)		(0.011)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-11,733		-11,670		-11,598	
Wald Chi^2	367		571		621	
Observations	465,960		465,960		465,960	
Panel D: Subsample of Single-Section Projects						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.029**	-2.83	-0.036***	-3.52	-0.035***	-3.48
	(0.011)		(0.012)		(0.011)	
County Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-16,041		-15,929		-15,829	
Wald Chi^2	307		446		893	
Observations	509,632		509,632		509,632	
Panel E: County-Firm Stratification						
Unexercised Investment Opportunities (Peers)$_{j,t}$	-0.032***	-3.18	-0.035***	-3.40	-0.038***	-3.74
	(0.010)		(0.011)		(0.010)	
County-Firm Strata	Yes		Yes		Yes	
$Pseudo-Loglikelihood$	-10,058		-9,953		-9,900	
Wald Chi^2	498		664		1,009	
Observations	537,093		537,093		537,093	
Firm-level controls	Yes		Yes		Yes	
Project-level controls	No		Yes		Yes	
Market level controls	No		No		Yes	